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THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, October 21, 1896.

MR. JOS. M. WILSON, President, in the chair.

THE IMPROVEMENT OF THE CHANNEL OF THE DELAWARE RIVER.

BY WALTER ATLEE, C.E., Member of the Institute.

The Delaware River is the largest tidal river in the world upon which a comprehensive improvement of the natural channel has ever been attempted. The magnitude of the problem is so much greater and the conditions so different that the precedents established in other tidal rivers do not apply, except approximately, upon the Delaware.

Notwithstanding the magnitude and the difficulty of the problem, the extent of the improvement of the natural channel of the river, which has been accomplished during the last ten years, is greater than that obtained during an

equal interval of time upon any river at all approximating the Delaware. While there yet remains much to be done in the improvement of the main ship channel between Philadelphia and the sea, that which has been accomplished is an admirable tribute to the means which have been employed and the skill which has directed these means. To a continuance of this skill and the methods of the past must we look for the final successful improvement of the Delaware River.

The improvement of the Delaware River, as a whole, has been divided into three sections, as follows:

(1) From Trenton to Fisher's Point, a distance of 29 miles.

(2) From Fisher's Point to Kaighn's Point, a distance of 6 miles.

(3) From Kaighn's Point to deep water in the bay.

Upon this first section, viz.: between Trenton and Fisher's Point (see plan), there has been no comprehensive project or estimate submitted beyond that required to obtain a channel 12 feet deep over Kinkora Bar. Kinkora Bar now carries a depth of about 8 feet at mean low water; the area between the mouth of the canal at Bordentown and White Hill carries a depth of about 6 feet, and the channel between Bordentown and Trenton has about the same depth at mean low water. The physical character of this division of the Delaware is such as to render its rectification difficult and very expensive. Its commerce has never been such as to press upon the attention of the Government the need for its extended improvement.

The second section of the river, that between Fisher's and Kaighn's Points, covers the improvement of the Philadelphia harbor.

The original project for this improvement was recommended by a Board of United States Engineers on March 30, 1888, and adopted by Congress in the River and Harbor Act of September 19, 1890. It proposes the formation, by dredging, of a channel about 2,000 feet wide, extending along the Philadelphia shore from opposite Kaighn's Point to opposite Fisher's Point, at a distance far enough removed

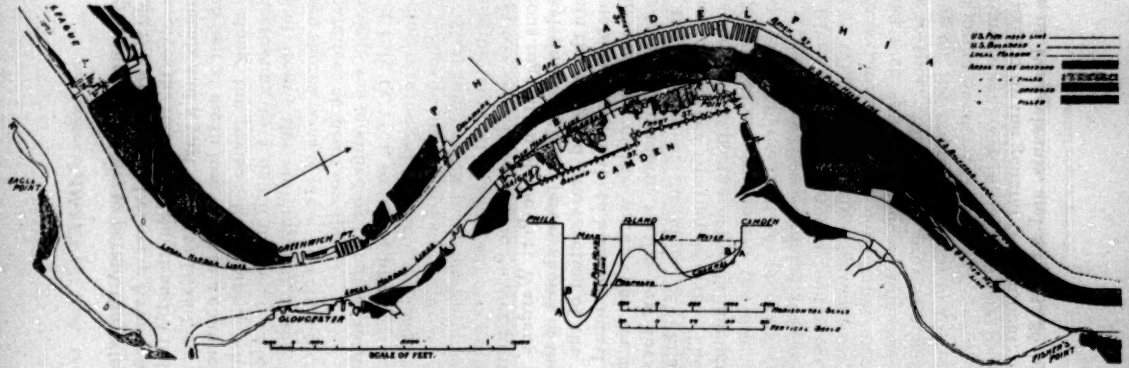


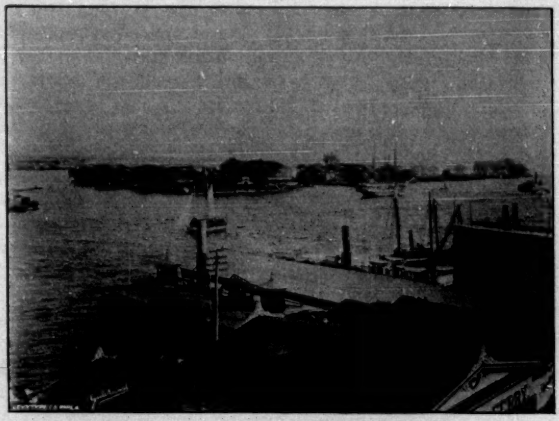
FIG. 1.—Sketch of Philadelphia Harbor.

from the present wharf line, to permit the extension of the wharves and the widening of Delaware Avenue at their shore ends. It involves the removal of Smith and Windmill Islands, adjacent shoals and a part of Petty Island, so as to give a depth of 26 feet at mean low water in a channel about 1,000 feet wide along the revised Philadelphia wharf line, this channel decreasing to a depth of about 12 feet along the Petty Island front; the building-out of the Philadelphia and Camden shores, so as to preserve a cross-section of about 55,000 square feet at mean low tide.

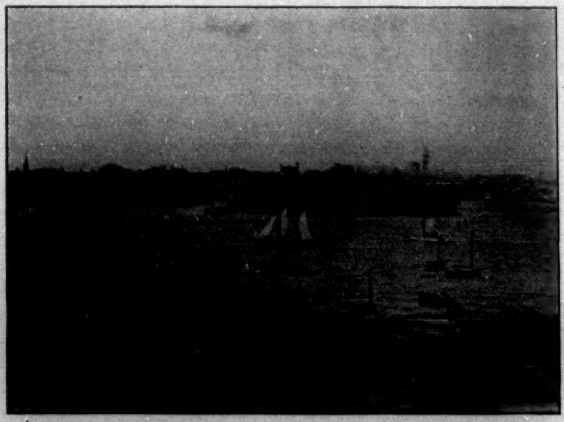
This project was modified by Congress in Acts of March 3, 1891, and July 13, 1892, so as to provide for the deposit and spreading of dredged material on League Island and elsewhere. The quantity of material to be removed was about 18,000,000 cubic yards, place measurements; the cost of the dredging required to carry out this project was estimated at $3,500,000. This scheme further provides for the simultaneous regulation of the Port Wardens' lines of both the Pennsylvania and New Jersey shores of the river, so as to maintain the assigned cross-section of the new channel and the establishment of these lines by actual construction during the progress of the work. The reconstruction of the water-fronts to conform to the new lines will be executed at the expense of the cities of Philadelphia and Camden and the other riparian owners. The cost of this reconstruction for that portion of the Philadelphia front from opposite Kaighn's Point to opposite the lower end of Petty Island, exclusive of the cost of property for widening Delaware Avenue, has been estimated at $8,000,000.

In the River and Harbor Act of September 19, 1890, the Secretary of War was authorized by Congress to enter into a continuous contract for the completion of this improvement, under such appropriations as Congress might make from time to time. Since 1890, provision has been made for carrying on the improvement by yearly appropriations contained in the Sundry Civil Bill.

The improvement was initiated in 1890 by an appropriation of $300,000 by the general Government, of $200,000 by the State of Pennsylvania, and $218,652.86 by the city of



Delaware River, from Philadelphia side, showing islands before removal.



Delaware River, from Camden side, showing islands before removal.

[Photographs by Gutekunst.]

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Philadelphia, for the purchase of the islands to be removed and the property thereon.

The total amount appropriated by the general Government up to this time for this work is $2,940,000, leaving $660,000 yet to be appropriated for its entire completion.

Previous to the removal of the two islands between Philadelphia and Camden, they caused the flood and ebb tides to pursue different paths, and so narrowed the channels, which were forced so near the shores as to prevent the construction of wharves necessary for the purpose of commerce.

In April, 1891, a contract was entered into for the execution of this work, but before the close of the following year it was annulled for failure "to prosecute the work faithfully and diligently."

Work was begun under a contract on June 1, 1893, by the American Dredging Company, of Philadelphia, and has been kept up almost continuously ever since.

This contract provides for the complete execution of the work, to be paid for as appropriations may be made from time to time by law, and for the continuance of the work as rapidly as may be required to the extent of dredging 400,000 cubic yards in any one calendar month, provided funds are available for payment therefor.

The work required the removal of all trees, structures, pile and timber wharfing and revetment from the islands. Their surface averaged about 9 feet above mean low water and about 3 feet above mean high water. The area of the islands to be removed was about 150 acres. A portion of the Windmill Island was revetted with crib work backed with stones. All timber had also to be removed from the dikes which formed the cross channel (see plan), also the removal by dredging and scouring of about 21,500,000 cubic yards of material.

In this work the American Dredging Company employed from 10 to 14 dipper and grapple dredges, manned by from 300 to 400 men, in excavating the material, which was placed in from 75 to 90 scows, each with a capacity of from 250 to 600 yards.

Three hydraulic dredges were employed to pump and spread the material from these scows, which was placed on League Island and elsewhere. From 18 to 25 steam tugs were employed in towing the scows from which the material was dumped. These tugs hauled from 4 to 14 scows at each tow, moving with the tides, their average round trip being from 20 to 50 miles.

The consumption of coal per month varied from 2,000 to 2,500 tons. There were also about 100 men employed in the repair and construction shops. The equipment represented an invested capital of $1,250,000. The material removed varied from clean sand and soft clay to hard clay and gravel.

There has been, so far, removed in all 24,848 linear feet of timber and revetment from Smith and Petty Islands and the shores and interior basin of Windmill Island; and the removal from the three islands and adjacent shoals of about 16,905,223 cubic yards by dredging, 3,252,148 cubic yards of which was deposited upon League Island, and the remaining 13,653,075 cubic yards was hauled away and dumped elsewhere.

The northern side of Petty Island has been dredged back to the New Jersey pier-head and bulk-head lines, giving, at low water, a width of 1,900 feet to the Pennsylvania channel, at this level.

All the pile and stone revetment and timber work have been removed, and the filling of spaces on League Island, as provided for in the contract, has nearly been completed. About 133 acres of land, formerly above low water, has been removed, and 282 acres, of which 135½ acres were on League Island and 146½ acres on Petty Island, formerly below, has now been raised above, high water.

At Five Mile Bar, which lies directly above the upper end of Petty Island, a dike has been constructed, extending from the New Jersey shore at Fisher's Point to within 2,000 feet of the head of Petty Island.

On June 30, 1890, this dike had reached an extension of 4,500 linear feet, which is its present length, of which the upper 3,500 feet consisted of random stone dike, founded

upon a brush mattress sill and backed with gravel and boulders derived from the excavation of the channel at Port Richmond, and the lower 1,000 linear feet of pile dike filled with stone. The tops of these constructions were carried to a height of 2 feet above mean high water. At the close of June 30, 1894, the action of the dike had formed a channel 13 to 15 feet deep and 270 feet wide across the bar. Before the formation of the dike, there was a depth less than 15 feet at mean low water, over a length of 1,200 feet, and a minimum depth of 3 feet. There is now a least depth of 23 feet over the whole length. The ledge opposite Otis Street has been entirely removed to a depth of 26 feet at mean low tide.

The increased depths which have been obtained by dredging have, in all cases, been permanent, even over the sites of Smith and Windmill Islands; where temporary deposits might have been apprehended, there is no indication of shoaling.

These deductions are derived from repeated surveys of the deepened areas, and from an experience covering active dredging operations extending over an interval of nearly four years.

The data required for the execution of the work, and the determination of its effects and changes during its progress, have been obtained from detailed hydrographic examination and surveys, based on a rigid system of triangles and range lines marked by natural objects, covering the entire distance from Fisher's to Kaighn's Points, 6½ miles. Tidal observations are registered by an automatic gauge.

The work already done upon the improvement of Philadelphia harbor has resulted in obtaining a channel at mean low water of a depth of 26 feet from Morris Street to Erie Avenue, a distance of $5\frac{45}{100}$ miles; from Morris Street to Shackamaxon Street, a distance of 14,120 feet. The channel has a minimum width of 225 feet, a maximum width of 1,000 feet, and a mean width of over 900 feet. The minimum width is only at one locality, dredged in 1894, to permit the laying of telephone and telegraph cables. Here the depth averages about 23 feet; this elevation has been left temporar-

ily during the execution of dredging above and below, in order not to disturb the cables. It will be removed as soon as the 1,000-foot channel in the immediate vicinity shall have been completed.

The next narrowest is 700 feet. The distances have all been measured from the new Philadelphia pier-head lines.

From Shackamaxon Street to pier No. 3, Richmond wharves, a distance of 7,675 feet, the maximum width of the channel is 1,000 feet, with a minimum width of 100 feet, or a mean width of 717 feet.

From pier No. 3, Richmond wharves, to Erie Avenue, it is 7,000 feet; the channel here has a maximum width of 950 feet, and a minimum width of 175 feet, or a mean width of 500 feet.

Smith and Windmill Islands have been removed to an average depth of 23 feet below mean low water.

The improvement of the third section of the Delaware River, viz.: between Philadelphia and the sea, was undertaken in accordance with a project and estimate submitted by a Board of United States Engineers on January 23, 1885. This project proposes the formation of a channel 600 feet wide and 26 feet deep at mean low water at all points where less width or depth occurs.

Before improvement, the channel had a depth less than 26 feet at mean low water, over an aggregate length of about 20 miles; and a depth less than 24 feet at mean low water over an aggregate length of about 6 miles.

The distance from Fisher's Point to deep water at the head of the bay is 61 miles.

The length of channel requiring improvement was, therefore, about one third of the total length.

There were six main locations where such improvement was necessary, as follows: Mifflin Bar, Schooner Ledge, Cherry Island Flats, Bulkhead Bar, Dan Baker Bar and Duck Creek Flats.

Except at Schooner Ledge, where the desired channel was to be obtained by dredging and the removal of rock, and at Cherry Island Flats, where dredging only was necessary, the plan proposed for obtaining the desired depth and

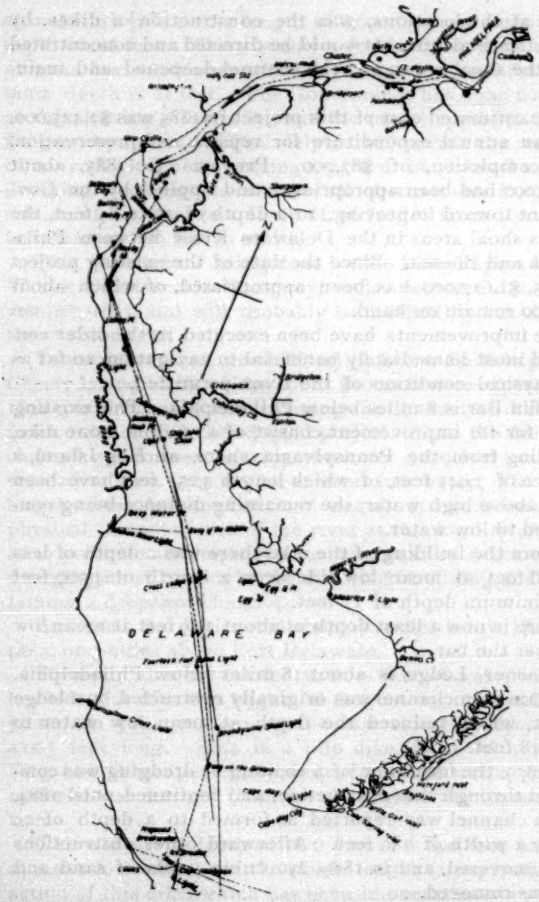

FIG. 2.—Sketch map of approach to Philadelphia harbor, showing the lights.

width at the locations, was the construction of dikes, by which the tidal currents would be directed and concentrated upon the shoal areas, and the channel deepened and maintained.

The estimated cost of this project in 1885 was $2,425,000, with an annual expenditure for repairs and preservation, after completion, of $87,000. Previous to 1885, about $1,500,000 had been appropriated and applied by the Government toward improving, to a depth of 20 to 24 feet, the various shoal areas in the Delaware River between Philadelphia and the sea. Since the date of the existing project in 1885, $1,617,000 has been appropriated, of which about $584,000 remain on hand.

The improvements have been executed in the order considered most immediately beneficial to navigation, so far as the physical condition of the river permitted.

Mifflin Bar is 8 miles below Philadelphia. The existing works for its improvement consist of a random stone dike, extending from the Pennsylvania shore, at Hog Island, a distance of 7,945 feet, of which length 3,257 feet have been raised above high water, the remaining distance being constructed to low water.

Before the building of the dike there was a depth of less than 26 feet at mean low tide over a length of 4,500 feet and minimum depth of 17 feet.

There is now a least depth of about 23·9 feet at mean low tide over the bar.

Schooner Ledge is about 18 miles below Philadelphia. The main ship channel was originally obstructed by a ledge of rock, which reduced the depth at mean low water to about 18 feet.

In 1879, the formation of a channel by dredging was commenced through this obstruction, and continued until 1884, when a channel was reported as formed to a depth of 24 feet for a width of 330 feet. Afterward other obstructions were discovered, and in 1889, 250 cubic yards of sand and rock was removed.

Before improvement, there were here, including the bar between the ledge and Marcus Hook, a depth less than 26 feet

at mean low tide over a length of 8,600 feet, and a minimum depth of 18 feet. There is now a depth of less than 26 feet at mean low water over a length of 7,850 feet, and the minimum depth is 21 feet. The Government has done no work at this locality since 1885; but the recent appropriation of $185,000 by the city of Philadelphia will permit the removal of the rocky ledge obstructing a part of the channel and the dredging necessary to remove all obstructions from this section of the river to a depth of 26 feet at mean low water in a channel 600 feet in width.

This work is now being done by the Philadelphia Public Works Construction Company, under contract dated November, 1895, and will probably be finished by the close of the current year.

Twenty-seven and one-half miles below Philadelphia is Cherry Island Flats. Here about $100,000 were expended in 1892–3 in deepening and widening the channel by dredging, in accordance with the adopted project. Since the deepened channel was formed, in 1893, the lower 4,000 feet has again shoaled to from 18 to 20 feet at mean low water. The entire length of the deepened channel was about 10,000 feet. The physical characteristics of the river at this locality are such as to preclude its improvement by means of dikes, and in dredging must be sought the means of obtaining and maintaining a deepened channel.

Bulkhead Bar is situated about 36 miles below Philadelphia, or 3 miles above Fort Delaware.

Formerly, this bar carried 20 to 21 feet of water at mean low tide. A dike was begun on August 25, 1890, and completed on June 30, 1892, on the east side, this dike being 4,063 feet long. This is a pile dike, filled with stones. Fifty-one thousand eight hundred and ten cubic yards of material was dredged from the channel during its construction.

There is now a depth of 28·6 feet and 600 feet in width at mean low water over the whole length (7,300 feet). The action of this dike, which has been in operation about three years, has been so extraordinarily favorable that very reasonable anticipations of its ultimate success may be in-

dulged in, and the permanent improvement of the bar accepted as almost demonstrated. Should this expectation not be entirely realized, it could undoubtedly be secured by comparatively small addition to the existing work of improvement.

Just above Bulkhead Bar there are the Pennsville Shoals; before improvement there was less than 26 feet depth at mean low water for 4,800 feet in length, with a minimum depth of 24 feet. Now, more than 26 feet, at mean low water, exists in depth over the entire length. This improvement is due to the action of the river under improved conditions.

The next locality below Bulkhead Bar requiring improvement is Dan Baker Shoal, 48 miles below Philadelphia. Here the river suddenly expands to a width of nearly 4 miles, and there exists an area in the main ship channel of several miles in length, with a depth of water of 20 to 24 feet. The Board of Engineers, of 1885, proposed for the improvement of this locality a dike about 5 miles in length, for the purpose of forcing the flood tide from the deep concavity on the west bank of the river below Reedy Island, and, conjointly with the ebb tide, secure a scouring action of the tidal currents along the main ship channel over the shoal areas forming the present bar.

This dike was to have been a low-water dike, and its average estimated cost was $324,000.

The dike was being extended under a recently executed contract, but all work thereon has been suspended under the provisions of the River and Harbor Act of 1896.

From the experience which has already been gained in the action of low-water dikes, it is highly probable that a low-water dike would not accomplish at this locality all that might be desired, and that it would ultimately require that the dike be raised to above high water; such a construction would probably increase the previous estimate to, say, $500,000. After the study which has been given to this locality, it is extremely probable that no better plan for the improvement of the Dan Baker Shoal can be suggested, unless recourse be had to dredging alone, than a dike on the

lines proposed by the Board of 1885, modified, however, by raising the dike to a height in excess of that proposed by the Board. It is also probable that the action of the dike would require to be supplemented by dredging a channel through such parts of the shoal areas as did not yield readily to the scouring action of the tidal currents. If such dredging became necessary, the estimate for the improvement of this locality would be increased to above $600,000.

At Duck Creek Flats, which is the next and last locality requiring improvement, the 26-foot curves of depth are separated by a distance of about 3 miles. For the improvement of this shoal, the Board of 1885 recommended a low-water dike along the west side of the channel, about 7 miles in length, at an estimated cost of $420,000. The dredging of a channel 600 feet wide and 23 feet deep would probably cost from $200,000 to $300,000, and, without regulating works, the utility of such a dredged channel might be of but short duration.

At Duck Creek Flats the physical characteristics of the river cease, and those of the estuary begin. Under such conditions, the improvement of the locality requires consideration differing from that which might be applied to localities further up the river. While high-water dikes of determinate length are required for the improvement of the river section, it is probable that dikes of less height, and on different lines, would be required in the estuary section of the river. Under the light of recent experience, it is impossible to revise the recommendations of the Board of 1885 for this locality.

The improvement of the Delaware River in the vicinity of Greenwich Point has never formed a part of the specific plan for either the improvement of the river or harbor, probably for the reason that the harbor improvement, when completed, would permit a passage of the main ship channel from the west side of the river, opposite Kaighn's Point, to the east side of the river opposite Greenwich Point. It would be to the advantage of the commercial interests at Greenwich Point if the 1,000-foot deep-water channel on the Philadelphia side of the river,

from above Kaighn's Point, could be carried continuously along the same side to below Greenwich Point. To accomplish this would require the removal of about 500,000 cubic yards of material, at an estimated cost of $280,000.

The improvement of this part of the river is now under consideration by the city of Philadelphia, with funds made available by recent appropriations of Councils, and probably will be accomplished at an early date.

The total length of channel in the Delaware River improved is 52,800 feet, or 10 miles. The total length improved to full depth is 23,020 feet, or about 4½ miles. At other localities the distance across the bars has decreased through natural causes, the aggregate decrease in length being 4,160 feet.

The full widths required by the project have been obtained at Five Mile Bar, Port Richmond, Otis Street wharf, Pennsville Shoals and Bulkhead Bar.

The benefits to commerce resulting from the improvements have been very great, especially those resulting from the removal of the two bars below Philadelphia. Previous to improvement, vessels of deep draught were compelled to utilize the high water of two tides in order to ascend the river to Philadelphia. They can now make the whole trip in a single tide.

DISCUSSION.

L. Y. SCHERMERHORN:—That which I shall say will not be a discussion of Mr. Atlee's able paper, but rather a brief statement of the reasons why we need an adequate channel to the sea, and what such a channel will accomplish for the commercial, industrial and maritime interests of the cities and States bordering the Delaware River; for, as Mr. Cramp has stated in his able letter, just read, this is a question of more than local interest, for its issues cover those belonging to States rather than communities.

Sixty years ago the ocean steamship was only a dream in the brain of Brunel, and was ridiculed by the directors of the Great Western Railway, when he, as their engineer proposed the steamship as a means for the extension of

their line across the ocean to our shores; nevertheless, their later faith in the possibility of such a dream permitted Brunel to build the steamship *Great Western*, which, in 1838, as the first ocean steamer, crossed the Atlantic and anchored in New York Harbor. This was accomplished in the face of demonstration by Dr. Lardner, the then greatest authority, that such a result was impossible. After this demonstration by Brunel, the problem was solved and the days numbered of the sailing ship as the only and best carrier.

The next great advance was the substitution, in 1845, of the screw-propeller for the side-wheel as the means for propulsion; since the latter date the wonderful advance which has been made in ocean steamships has simply been in better and larger hulls and motive-power construction.

The development of steamships to the date of less than twenty years ago, except in rare instances, had produced an ocean freight carrier with a length of less than 300 feet, with a loaded draft of less than 20 feet, and with a carrying capacity of less than 4,000 tons. At that time the leading seaports of the North Atlantic—Boston, New York, Philadelphia, Baltimore and Norfolk—all carried a sufficient depth of water over their harbor or channel bars to freely admit the standard ocean steamship. Under such conditions wharves of 200 or 300 feet in length, such as we had in Philadelphia, and the depth of 20 feet which existed over the bars in the channel of the Delaware River, was enough to allow the ocean carriers of the world to commodiously reach us and permit the port of Philadelphia to carry on a business which was fairly competitive with its rival ports. The port of Philadelphia then stood in commercial importance next to New York, and thereby ranked as the second in the United States; to-day its position is a doubtful fourth, and the causes which have largely contributed to such a condition are as follows:

Competition in business always tends to the lowering of prices on one hand, and the effort to meet the reduced profit by cheaper methods on the other hand. Experience has demonstrated that ocean freight can be more economically carried in larger hulls with greatly increased motive-power,

designed to shorten the time of ocean transit and also reduce the consumption of coal and thereby the quantity carried; accordingly, ocean steamships were designed with largely increased dimensions and motive-power, which greatly economized the amount of fuel formerly required. As a result, the modern ocean freight steamship, as a type, is represented by such dimensions and capacities as the following: the *Cevic*, 500 feet long, 9,000 tons capacity; *Prussia*, 445 feet long, 7,000 tons capacity; *Southwark*, 480 feet long, 10,000 tons capacity; and lastly, the *Pennsylvania*, 585 feet long, and 20,000 tons capacity.

The standard steamship of a few years ago carried less than 4,000 tons, required docks and wharves less than 300 feet long, channel depths not exceeding 20 feet, and carried between Europe and the United States 4 tons of freight to each ton of coal expended on motive-power; the steamship of to-day carries 10,000 tons of cargo, demands docks and wharves about 600 feet long, channels 30 feet deep and carries 8 tons of cargo for each ton of coal consumed under her boilers.

The seaports of Boston, New York and Baltimore met these increased demands, and provided, several years ago, longer wharves and increased harbor and channel depths, while Philadelphia waited until her ocean commerce had well-nigh passed to other ports before she awoke to the full realization of the situation. Rival ports that met the demands of modern steamships received the trade and commerce that by position and geographical advantage belonged to Philadelphia, simply upon the principle of the survival of the fittest. We can only exist as a seaport so long as we demonstrate our right to exist, which means that we fully meet the requirements that competition has thrown around the successful operation of the modern steamship and its traffic. When this shall have been done, there is no just reason why we should not soon be able to restore the lost prestige of our port and place it where it properly belongs, the second commercial port of the United States.

After our sleep I believe we are again awake and fully aroused to the exigencies of the times; within one year from

to-day our harbor improvement will be completed, and with it a large number of new docks and wharves fully adjusted to modern steamships, a widened Delaware Avenue; and I dare almost prophesy that within the same year we will have a deep-water channel to the sea, clear and unobstructed. This is our hope and aim, and to such as are here before me we appeal for your encouragement and aid; and while you plan and labor for better streets, purer gas and clearer water, do not forget the need of a better channel to the sea.

PROF. L. M. HAUPT, in response to a request from the President, called attention to the desirability of rapidly improving the depths in the Delaware River. He believed dredging would have to be relied upon mainly for maintenance, and that it would be much more economical, ultimately, to place the material on shore by the improved hydraulic plants now available than to replace it in the river.

He could not endorse the statement in the paper that: "The increased depths which have been obtained by dredging have, in all cases, been permanent, etc.," and cited only a few of the many well-known instances where the facts were decidedly at variance with the statement, as at Kinkora Bar, dredged to over 12 feet, with material placed on opposite bank of stream, which shoaled soon after to 8 feet or less; also at Cherry Island Flats, dredged in 1893 to 26 to 27 feet, shoaled within a month after the completion of contract to 19 to 21 feet; the material, amounting to over 960,000 cubic yards, having been placed on the slope of the flats above the cut. The harbor of the Chesapeake and Delaware Canal Company, at Delaware City, was dredged in July last to 15 feet, but shoaled in about nine weeks to 8 feet, or at the rate of nearly a foot per week from the material now being dumped on the Pea Patch Shoal, just above this point.

Professor Haupt thought it was a mistake to side-track the upper river section of 30 miles of this magnificent waterway with the remark that: "The physical character of this division of the Delaware is such as to render its rectification difficult and very expensive. Its commerce has never been such as to press upon the attention of the Gov-

ernment the need for its extended improvement," since its commerce, over twenty-five years ago, exceeded 4,000,000 tons, and there would seem to be no serious difficulty in securing at least 15 feet at low, or 21 feet at high water.

If any encouragement were given to this river as an outlet to the sea via Raritan Bay, the commerce would, he believed, soon reach or exceed 10,000,000 tons, and effect great economies in transportation and manufactures.

As to the dike question, he preferred high, water-tight structures, believing them to be more effective in regulalating the currents, and thought that the policy of improvement, by removal of bars, should begin at the mouth of tidal rivers and proceed up stream, to let in the tidal volume more freely; and he did not wish to be understood as in any way opposed to the rapid prosecution and early completion of the work, but, on the contrary, desired to see everything done to further that result and secure comparative permanency of channel depths.

A MEMBER:—The project for the new harbor improvement in front of the city involved the removal of 16,905,223 cubic yards by dredging; 13,653,075 cubic yards were dumped in the river, and 3,252,148 placed on League Island. What is the status of the large amount placed in the river behind Little Tinicum Island and at Red Bank and opposite Marcus Hook?

L. Y. SCHERMERHORN:—In justice to my convictions and the facts in the case, I cannot remain silent under the criticisms which have been made as to the methods adopted by the Government engineers in carrying on the improvement of our river and harbor, and especially the criticisms relating to the disposal of dredged material. Theory is one thing, but facts are sometimes another, and in this matter the latter are directly opposed to the former. In general terms, the statement has been made that the material dredged from one part of the river is re-deposited in another under such conditions as to permit such material to find its way again into the navigable channels; if such were true, the propriety of the statements to which you have listened would be manifest. That they are not even approximately

true, I know. The improvement which has been accomplished and that which yet remains to be done, for an improved harbor with all of its needed facilities, with a deeper channel between Philadelphia and the sea, has been obtained, and will be carried to final completion through the earnest, intelligent and untiring efforts of public-spirited men, even though handicapped at times by the opposition of a few who have hung, like a mill-stone, upon the neck of the enterprise.

Dumping-grounds, for the deposit of the dredged material, were selected by the Government engineers at localities where, after careful examination, they felt every assurance that it could not result in an injury to the main ship channels. Not satisfied with resting such assurance upon theory, repeated surveys have since been made of these places of deposit, and, as a result, it is found that their anticipapations were in all cases correct, and that the material placed in these dumping-grounds has remained therein within very narrow limits, and not, as here stated and elsewhere sometimes asserted, washed again into the navigable channels. This is as true of the Cherry Island dump as of the others, and, while admitting that the channel dredged at the last-named locality a few years ago has shoaled, it has nevertheless shoaled from causes outside of the dumping-ground question.

In reply to the query, "what is the status of the large amount of material placed in the river behind Tinicum Island, at Red Bank and opposite Marcus Hook?" I would say that at these localities has been deposited, without injury to the river, the larger part of the material removed from Philadelphia harbor and not placed ashore. From time to time surveys have been made of these dumping-grounds, and their results show that the material deposited therein has remained where it was originally placed.

For several years, all material dredged from the bars of the river was placed ashore, at greatly increased cost, and as is now being advocated by Prof. Haupt; and yet, during and following such a method, these same channels re-shoaled at a rate not one whit less than that which had previously

existed; and yet, we are told that former methods, which proved unsuccessful, should again be adopted as a panacea for the same evil. I am glad to say that such adverse criticism has had but a small following. The leading commercial and maritime bodies of our city have reason to hold in high estimation the judgment of the Government engineers, and have repeatedly declared their faith in the propriety of their methods. The judgment of these bodies has been founded on fact, and I have very briefly attempted to place such before you; at all events, I feel assured that what I have stated is fact, and not imagination or theory.

MR. EDWIN F. SMITH, M. Am. Soc. C. E.:—A deep-water channel to the sea is a matter of the greatest importance to the city of Philadelphia. Situated as the city is, 120 miles inland on a tidal stream, she will be placed at a disadvantage in her commercial relations with foreign countries as long as the largest vessels cannot have perfect freedom of movement to and from her wharves.

Early in the century, Philadelphia enjoyed the proud distinction of being in the front rank among American cities in the magnitude and importance of her commerce. Her ships were to be seen in every quarter of the globe, and to the enterprise of her merchants in those days, more than to any other one thing, is to be attributed her growth and development into the largest manufacturing center, and the third city in population, in the Union to-day.

But with the enlargement of the transportation facilities of the country, the multiplication of transcontinental trunk lines, and the employment of vessels of deeper draught and larger carrying capacity in foreign commerce, there has come about a change in the relative position of Philadelphia, and her foreign trade has been gradually slipping away from her grasp.

Boston, New York, Baltimore, Norfolk, and even New Orleans and Galveston, are reaching out for the tempting prize of commercial supremacy through the avenue of deeper channels to the sea.

New York has 30 feet depth of channel at mean low water, and Baltimore is now working for the same maximum

depth. The mouth of the Mississippi River was long ago improved by the Government by the building of the Eads jetties, and the depth over the bar at Galveston has been increased so that vessels of deep draught can enter that port. The railroad and other facilities at these Southern ports for the prompt and economical trans-shipment of freight directly from the cars on the wharf, or from elevators, have kept pace with the harbor improvements, and to-day are drawing trade away from the Northern ports.

I have been deeply interested in the paper which has just been read by Mr. Atlee, and in its discussion by Mr. Schermerhorn and Prof. Haupt, and can really add but little to what has been said.

Nevertheless, there are two important divisions into which this subject may be divided, namely:

(1) The depth of channel which it is possible to attain.

(2) The means to be adopted to maintain that depth.

As bearing on the first proposition, I quote from the Report of the Board of United States Engineers, for the year 1894:

"The present, and probably ultimate, greatest available depth that can be maintained for the navigation of the Delaware River is *about 27 or 28 feet* at mean low water. For long stretches of many miles of main channel the existing and possible depths do not exceed this, while the actual draught required for the commerce of the river is in excess of 25 feet."

In the light of the facts before us, no such depth of channel as 27 feet at mean low water will answer for the Delaware River if Philadelphia is to retain her fair share of the commerce of the country.

In proof of this fact, we have this warning from Mr. Higbee, of the International Company, who has said, recently:

"Most of the company's vessels *can be loaded to a draught that cannot be navigated in the Delaware River*, and the problem was reduced to making the draught as light as possible with the best cargo. Vessels are now loading to a draught of 26 feet. The International Line vessels could be loaded 27 feet."

As there is less than 20 feet depth at mean low water over portions of Cherry Island Flats, we can easily understand why it has been necessary for the International Company to withdraw its largest freighters, the *Kensington* and *Southwark*, from Philadelphia and place them at New York.

I am impressed with the belief that every effort should, for the present, be directed to obtaining a depth of 27½ or 28 feet, at mean low water, and later on, if possible, 30 feet. The latter I know would be a difficult and costly undertaking, as is evident from an inspection of the profile of the bed of the river; but when we consider such works as the Manchester Ship Canal, and the removal of that ancient barrier, the Iron Gates of the Danube, just accomplished, I think we need not shrink from undertaking any improvement that has been suggested for the Delaware.

As to the means to be employed for accomplishing the work, I may say that, from long experience with the improvement of river channels on a smaller scale, I am a firm believer in the efficacy of dikes in maintaining a given depth.

They should, however, be carried up at least to the level of high water, if not above. Dikes built to low water only do not sufficiently contract the tidal currents, nor give the maximum of scouring effect. This would appear to be the situation at Dan Baker Shoals.

The width of channel in such cases, also, should be sufficient for the free movement of vessels of the largest class, for which purpose a width of 1,000 feet would seem to be necessary. Mr. Cramp has alluded to the possibility of trouble with ice in the channel between dikes, but I think this might all be overcome by the use of larger and more powerful ice-boats, of a different pattern than those now in use, as is now the practice on the Great Lakes.

Another means of accomplishing the end is by dredging, and much has already been done, both by the United States and by the city of Philadelphia, in the removal of the islands in front of the city, and in deepening the channels at the six principal locations below Philadelphia, named by Mr. Atlee.

At some of these locations, notably Cherry Island Flats, continual dredging will be necessary in order to maintain a channel, and the deeper the channel the more difficult it will be to maintain it.

This being the case, the necessity of confining the depositing of dredged material to locations from which it will surely not reach any part of the navigable channel is apparent. There will always be a large annual amount of dredging work to be done in the Delaware River, and hence the necessity for making the best possible disposition of the material.

I am glad to hear reference made to the fact that the improvement of the navigable channels of our great rivers is of national and not merely local importance. Certainly, the whole nation is interested in the navigation of the Great Lakes, and of the Mississippi, the Ohio, the Hudson, the Delaware and other rivers upon which there is a considerable volume of traffic. Each section of this vast country has its own peculiar needs for Government aid in public works, and no one section should look with disfavor on an expenditure in another, when it is for the public good.

I am glad, too, to see so great interest taken in the agitation of this question, and shall hope to see it continue, until the harbor of Philadelphia shall be as easy of access from the sea as any port in the country.

PROF. HAUPT, in view of the fact that certain matters appear in the printed copy of this discussion, which were not presented at the meeting, submits the following supplementary statements:

Mr. Schermerhorn states that if it were true "that material dredged from one part of the river is re-deposited in another under such conditions as to permit such material to find its way again into the navigable channel, the propriety of the statements (made by the writer and others) would be manifest." He adds that these statements are not even approximately true, and says: "These same channels re-shoaled at a rate not one whit less than that which had previously existed."

Now as to the facts: The official report of the United States

Government states very clearly, on page 1,023, Report for 1895, in speaking of the channel at Cherry Island Flats: "The formation of a channel west of the flats, having a width of 470 feet and a depth of 24 feet M.L.W., was commenced in 1879 and completed in 1884, the length of the cut being nearly 2 miles. In this work 1,594,740 cubic yards of material were removed by dredging at a cost of $400,000." (This was placed on shore by handling twice, hauling over the flats on trains, dumping and spreading, at an average cost of less than 25 cents per yard.) Previous reports state that the cut shoaled very slowly, and this report (1895) remarks that "an examination made in May, 1892, showed that the channel had shoaled about 1·2 feet over a distance of about 10,000 feet." (That is in the eight years (1884-92) the shoaling had been about 14 inches or *less than 2 inches a year*.) The report adds:

"In 1893 the channel was dredged over a width of 400 feet, and to a depth of from 25 to 27 feet, M.L.W. Soon after the completion of the work,* the channel shoaled to a depth of from 19 to 21 feet over the width dredged, for a distance of about 4,000 feet, but the material is very soft and has not obstructed the passage of vessels."†

This contract was let to the American Dredging Company, which was permitted to deposit the spoils about a mile above the cut on the slope of the flats, and the examination was made within a month after the completion of the contract, with the astonishing results thus officially vouched for, viz.: That it had shoaled from 25 to 19 or from 27 to 21 feet in so short a time as a few months—*six feet*, as compared with the previous rate of less than *two inches* in a year. In view of these facts, how are we to interpret the statement that the rate is not one whit less than before?

There can be but one conclusion, yet we are told that this shoaling came from *other* sources, although there was no deposit made in the river at or near this cut at that time, and the dump was observed by pilots to disappear rapidly,

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* October 29, 1893.

† What can this mean?

as averred by their statements relative to their ability to sail their vessels over the dumping ground a short time after the deposits were made. Mr. Schermerhorn, President American Dredging Company, attempts to explain this by the comprehensive but unsatisfactory statement that "it shoaled from causes outside of the dumping-ground question," but he does not enlighten us as to their causes nor their origin, as they did not exist before.

Upon the general question of the re-formation of shoals from material dumped back into the river and not restrained by dikes, a special board of United States Engineers, appointed to consider this very problem, says: "The action of the currents upon the ordinary materials dredged and re-deposited, as on sand and mud, is to at once redistribute them. The use of dumping scows, dumping in from 7 to 11 feet of water, would, in effect, place the dredgings upon the channel slopes and insure their being immediately transported to other points possessing no excess of depth."

"To the improvement of Cherry Island Flats these considerations have special reference, etc." * * * "The Board is unanimously of the opinion that such action (dumping in the river either by the United States or others) would be prejudicial to navigation."

And with reference to the site recently selected for the deposition of over 1,200,000 cubic yards on the western slope of Pea Patch Island at Fort Delaware, the same Board says: "It has already an insufficient depth and no dumping should be done in it."

The effect of dumping here was so marked that, in response to the protest of the citizens of Delaware to Senator Gray, it appears to have been suspended, and the scows are now discharging on the Goose Island Flats below the Finn's Point jetty. The Superintendent of the Chesapeake and Delaware Canal wrote, October 17, that their harbor was dredged, by themselves, to 15 feet M.L.W. on July 31. "To-day we have about 8 feet," from a survey made ten days ago, and confirmed by that made "by the Government Engineers this week." "Such a rapid filling up has never before occurred." "It is caused by the vast amount of mud

the contractors have been dumping in our immediate neighborhood."

Again, the League Island docks shoaled to the extent of 50,000 yards in nine months, while the obstructions back of Tinicum and in front of the former Lazaretto are reported to have been washed away by the currents, and to have gone out into the river. These and many other facts might be stated on credible authority to confirm the position taken by the Board of United States Engineers and others, as well as by the writer, as to the injury to the river and delays in securing results in our efforts to obtain a deep water-way to the sea.

The following contributions to the discussion have been received by the Secretary of the Institute in correspondence:

MR. CHAS. H. CRAMP:—The paper offered by Mr. Atlee is a valuable and interesting contribution to the literature of the subject—the improvement of the Delaware River and the harbor of Philadelphia.

It is the most complete *résumé* of the legislative and executive history of the scheme that I have seen.

So far as it touches upon the civil engineering problems involved, it is beyond criticism.

There is, however, one problem which I have not seen discussed in any of the numerous papers and reports upon the subject that have come to my notice.

That is the ice problem, and, from the standpoint of practical experience, which is naturally my point of view, that is one of the most serious difficulties to be dealt with.

At best, a tidal river is a difficult thing to deal with in hydraulic engineering, and the difficulty is greatly increased and complicated when large masses or fields of ice are encountered on its surface nearly every season.

Under such conditions, the deepening of a channel for navigation forms only part of the necessary provision. In addition to this, the natural, or undeepened, part of the river should be kept free from surface obstructions that will intercept the flow of water, whether it is coming in or going

out of the whole tidal system, keeping in view at all times that the greater the volume of water that enters the system the larger or greater the amount that goes out, thereby promoting any necessary scouring the proposed channel may need.

These surface obstructions prevent the free passage of ice fields, which form rapidly on the surface when the temperature falls to 20° or below. We all know that the wider the surface the more easily the fields pass out to the sea.

For these reasons I would object generally to high-water dikes or jetties, and would also suggest the least possible narrowing of the river itself, as distinguished from the channel proper.

High-water jetties, with sharp, boat-shaped ends, when run in the direction of the river, are not so objectionable.

I offer this in a suggestive, rather than in an argumentative way. In fact, I assume that, while no mention has been made of this branch of the subject in any published matter that I have seen, it has received the attention of the engineers in their own discussions and calculations.

The general channel scheme, so clearly described by Mr. Atlee, is comprehensive and excellent. But I would consider it only a good beginning; 26 feet depth and a mean width of 700 feet is not enough for the up-to-date requirements of our heavy commerce and shipbuilding necessities, to say nothing of the probable developments of the near future.

We have already seen the large new freighters of the International Company (the *Kensington* and *Southwark*) forced to cease plying to this port. The Cramp Company has, in the past ten years, built ten vessels for the navy and several large merchant and passenger ships, including the *St. Louis* and *St. Paul*, which required two tides to get up or down the river at normal draught; and, even at that, some of them have dragged in the mud at various points not by any means the worst, when they happened to be caught there at any stage of water less than mean high.

For safe and sure navigation a ship should always have some clear water—at least 2 feet—under her keel. She

should also have width at least equal to twice her length for any emergency, such as impending collision with a sailing vessel, that might require turning or a quick sheer out of her course.

Twenty-six feet by 700 feet will not afford these conditions to all ships that would like to ply to this port, or are likely to be built here.

Thirty feet by 1,500 feet would be nearer the mark of the actual present requirements of the commerce and industries of Philadelphia, and such dimensions of channel will be crowded to their utmost capacity by the development of the near future.

I have noticed in the current discussions of this subject by prominent men and the newspapers of Philadelphia, though I see none of it in the paper of Mr. Atlee—which is purely historical and technical—a tendency to what I consider an undue and possibly injurious exploitation of the purely local advantages which Philadelphia alone is to derive from the perfection of the proposed scheme of river and harbor improvement.

For my part, whenever I have had occasion to offer argument or suggestion in favor of the improvement, I have based it upon broad and general commercial grounds, viewing the benefit to Philadelphia in particular as incidental or consequential thereto.

It is true that Philadelphia is a very great commercial city, and that her interests will be subserved by improvement of navigation upon the Delaware and the consequent enlargement of her commercial facilities; but that is not the only reason why these things should be done, and, in fact, it is not the main reason.

Whatever conduces to the enlargement of the commercial facilities of Philadelphia benefits alike the people of a very wide area of country, which includes Delaware and New Jersey. Therefore, everything which conduces to enlarge her facilities as an entrepot, must confer benefits in all directions tributary to the river and the bay.

If Philadelphia were not here there would be no occasion for the proposed improvements; the presence of the city

here makes the improvements necessary to the general commercial welfare and prosperity of the American people. In other words, I might say that Philadelphia is the cause of the improvements; the improvements are not the cause of Philadelphia.

If I had time I would go into particulars, illustrating, for example, by the fact that the wealth of the State of Delaware is, so far as her population and resources go, in every square of her towns and in every acre of her agricultural area, equally interested with Philadelphia in the proposed improvements. This fact is so apparent that I do not consider it necessary to amplify upon the statement. The logic of it may be applied generally to New Jersey and all other localities which employ or would employ Philadelphia as a channel through which to conduct commercial intercourse with the outside world, or whose development is in any way associated with or contingent upon the improvements of Philadelphia.

As I have already intimated, even if there ever were valid arguments against the establishment of great commercial entrepot on the site of this city, the time for their advancement has long since past, and it is too late to discuss that class of questions. The city is here, and the growth of two centuries has created interests and established a foothold which must be permanent; anything that would tend to impair the foothold or imperil these interests would be as disastrous to the whole region as it would be to the city itself.

The problem is to deal in the most effective and permanent manner with the difficulties which exist, and to remove any obstacles that may be in the way of the best and widest realization upon the basis of things as they are. For these reasons it would afford me great pleasure to see a broader and more thoroughly national scope given to the advocacy of these great improvements than I have seen in previous discussions. Of course, as I said at the outset, Mr. Atlee's paper does not itself invite this class of suggestions.

With regard to the proposed extension of the main ship channel from its present southerly termination to connect

with the channel below, thereby opening the southern water-front of the city from Greenwich Point down, to commercial uses, I remark that the desirability of its completion from every point of view is too obvious for comment.

The only suggestion I would offer in these premises is to repeat the previous one, namely, that whatever may be done in this direction should be done without the erection of any fixed obstructions in the river—using the word "river" here, as heretofore, to embrace the whole sheet of water and not the channel alone.

If this scheme is carried out logically, it is suggested that the removal of certain existing obstructions, such as Greenwich Point and certain islands in the river and bay below, would be necessary.

In conclusion, I would remark that whatever may be the scheme at any point in the region of improvement, it should be based upon the principle of providing for the most copious and least obstructed inflow and outflow of water under natural conditions.

Care should be taken to facilitate as much as possible the exit and the breaking-up of ice-fields, thereby shortening the period of danger to navigation from that cause, if not averting it altogether.

When the total benefit, or, perhaps, it would be better to say the total national profit, to accrue from these improvements in the long run is considered, any question of immediate cost becomes immaterial.

J. R. SELFRIDGE, Lieutenant-Commander, U. S. N. (late in charge of the Branch Hydrographic Office at Philadelphia):—* * * I trust, in the discussion which follows, a plan for the formation of a Board of River Commissioners will be suggested, in which the interest of all branches of the marine profession will be represented.

In my opinion, it should be composed of five members, as follows:

Two gentlemen most widely known and respected in marine circles.

One civil engineer.

One army officer, of the engineers.

One naval officer, presumably the inspector of the light-house district.

The appointment of the latter is essential, in view of the importance of a sufficient water-course for our battleships, and the selection of the officer most acquainted with the changes in the hydrography of the river. The naval inspector of lighthouse for the district seems appropriate.

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WASHINGTON, D. C., October 19, 1896.

MR. E. R. SHARWOOD, Secretary, The Philadelphia Maritime Exchange:—* * * Referring to your valued favor of the 24th Oct., * * * in which you do this Exchange the honor to suggest that any contribution from it upon the subject of Mr. Walter Atlee's address on the improvement of the channel of the Delaware River before the Institute, on Wednesday, October 21st, would be acceptable for printing in the *Journal of the Institute*, in connection with the proceedings of the meeting, I have the honor to hand you herewith copy of preamble and resolutions unanimously adopted at a special meeting of our Board of Directors, on October 15, 1896, and also a copy of a resolution of confidence passed by the Joint Executive Committee on the Improvement of the Harbor of Philadelphia and Delaware and Schuylkill Rivers, of which this Exchange is a member, adopted May 11, 1896.

It is unnecessary for me to add that this Exchange is very deeply interested in the improvement of the Delaware River, and has given much time and thought to the subject.

THE PHILADELPHIA MARITIME EXCHANGE,
PHILADELPHIA, October 30, 1896.

At a special meeting of the Board of Directors of The Philadelphia Maritime Exchange, held the 15th day of October, 1896, the following preamble and resolutions were unanimously adopted:

Whereas, The welfare of the maritime and commercial interests of the port of Philadelphia is intimately connected with the improvement of the channel of the Delaware River at both Schooner Ledge and Cherry Island Flats; and

Whereas, The early completion of these improvements might be delayed, if value were given to the criticism which has been made of the present method of disposing of material dredged from these channels; and

Whereas, The experience of the past justly entitles the plans and methods of the United States Engineer Department to be received with the highest confidence; therefore,

Resolved, That The Philadelphia Maritime Exchange protests against the unwarranted criticism and censure of the methods of the Government in carrying on these improvements, and reasserts its confidence in the propriety and success of the plans which are in operation for the improvement of the localities named.

Resolved, That a copy of this action of The Philadelphia Maritime Exchange be transmitted to the Secretary of War and to Major C. W. Raymond, Corps of Engineers, U. S. A.

PHILADELPHIA, October 15, 1896.

Resolution of confidence by the Joint Executive Committee above named in the skill and ability of the U. S. Engineer officer in charge of Delaware River improvement:

Resolved, By the Joint Executive Committee on the Improvement of the Harbor of Philadelphia and the Delaware and Schuylkill Rivers, consisting of representatives of the Philadelphia Board of Trade, Philadelphia Commercial Exchange, The Philadelphia Maritime Exchange, Philadelphia Drug Exchange, Grocers' and Importers' Exchange, Vessel Owners' and Captains' Association, Board of Port Wardens, Manufacturers' Club and Board of Harbor Commissioners:

(1) That we seriously deprecate the criticisms upon the United States Engineers which have recently been referred to in some of the newspapers in their discussion of the River and Harbor Bill now pending in Congress, which criticisms we believe to be unfounded in fact and unauthorized by any proper engineering authority:

(2) That the commercial and maritime organizations of Philadelphia hereby renew their expression of confidence in the skill and ability of Major C. W. Raymond, U. S. Corps

of Engineers in charge of this district, and also their confidence in the plans, repeatedly framed, extended and approved by the engineers of the War Department since 1885, under which the work of improving the navigation of the Delaware River is being conducted; and that they consider the work already done under these plans as eminently satisfactory in its results.

PHILADELPHIA, May 11, 1896.

MR. FRANK J. FIRTH, President, The Erie and Western Transportation Company:—* * * There is no doubt that the city of Philadelphia will continue to be at a commercial disadvantage in its effort to share in the export and import trade with competing seaboard cities until it can command as cheap ocean service as they do. This cheap ocean service cannot be had until the Delaware River offers a channel not less than 26 feet deep on minimum low water, thus enabling large modern vessels, drawing, say, 30 feet, to pass in and out freely on high water.

The work of improving the channel is now under contract to an extent that, it is understood, will insure the full depth of water required to a point, say, 48 miles below the city, early in 1897. The work is in the care of engineers of the United States Government, and it certainly would be a grave misfortune if the progress of the work should be checked by any discussion or differences of opinion among our citizens or commercial bodies as to the particular form of dredge to be used on the work, or whether the material removed should be deposited on shore or in suitable places in the river. Citizens of Philadelphia, interested in the growth of its foreign and coastwise trade, will do well to concentrate their efforts on urging the promptest possible completion of the channel improvement, leaving the engineering details with the U.S. Government Engineers, where they properly belong.

PHILADELPHIA, October 30, 1896.

MR. WM. R. TUCKER, Secretary, Philadelphia Board of Trade:—* * * Since the year 1874 I have taken a deep interest in the improvement of the Delaware River, and have been intimately associated with all the efforts made

by the commercial and maritime interests of Philadelphia to impress upon Congress the vital importance of appropriating such amounts as would permit the removal of the shoals obstructing the safe and speedy navigation of vessels of the deepest draught between this port and the sea. I have therefore read, with more than ordinary interest, Mr. Atlee's able review of the work upon the ship channel, and I heartily endorse his words of commendation for the United States Engineers, when he says: "The extent of the improvement of the natural channel of the river, which has been accomplished during the last ten years, is greater than that obtained during an equal interval of time upon any river at all approximating the Delaware," and "that which has been accomplished is an admirable tribute to the means which have been employed and the skill which has directed these means," ending up with the none too great compliment that "to a continuance of this skill and the methods of the past must we look for the final successful improvement of the Delaware River."

During the early stages of the work of the removal of Smith and Windmill Islands, the amateur hydrographers and encyclopædic engineers were pleased to burden the public prints with continued criticisms as to the plans of the engineer in charge of the work, and asserted and re-asserted that the removal of the islands would increase the cross-section of the river abreast of the city, and would prevent the maintenance of the depths secured, unless solid piers should be constructed simultaneously with the removal of the islands. Fortunately, at that time little attention was given these theorists; for we are now told by Mr. Atlee that "the increased depths which have been obtained by dredging have, *in all cases*, been permanent, even over the sites of Smith and Windmill Islands; where temporary deposits might have been apprehended, *there is no indication of shoaling*."

Mr. Atlee adds: "These deductions are derived from repeated surveys of the deepened areas, and from an experience covering active dredging operations extending over an interval of nearly four years."

The criticisms which have appeared for some time past as to the plans of the United States Engineer Department for conducting the work of improvement upon our rivers are to be regretted. * * *

The Joint Executive Committee on the Improvement of the Harbor and the Delaware and Schuylkill Rivers, representing the trade, commercial and maritime associations of Philadelphia, has placed itself upon record as having entire "confidence in the plans, repeatedly framed, extended and approved by the Engineers of the War Department since 1885, under which the work of improving the navigation of the Delaware River is being conducted, and that they consider the work already done under these plans as eminently satisfactory in its results."

The Board of Trade and Maritime Exchange have quite recently endorsed the joint committee in commending the plans and work of the Government Engineers.

The following is a copy of the preamble and resolutions unanimously adopted by the Philadelphia Board of Trade, at a meeting held on October 19, 1896:

Whereas, The success of Philadelphia as a commercial port is largely dependent upon the earliest improvement of the navigation of the Delaware Bay and River; and

Whereas, It is believed that the United States Engineer Department is fully alive to the great importance of completing the work of the said improvement, and has adopted engineering methods calculated to secure the best and quickest results for the amelioration of the conditions so unfavorably affecting Philadelphia as a seaport; and

Whereas, The highest confidence is entertained in the ability and integrity of purpose of the United States Engineers—a confidence warranted by the experience of the past; therefore,

Resolved, That the Philadelphia Board of Trade deprecates the unwarranted criticisms of the plans of the United States Engineers for carrying on the improvement of the channel-way of the Delaware Bay and River, having every confidence in the wisdom and ultimate success of their methods and plans.

Resolved, That a copy of the foregoing be transmitted to the Secretary of War and Major C. W. Raymond, Corps of Engineers, United States Army.

PHILADELPHIA, November 2, 1896.

ON THE ORIGIN OF ATMOSPHERIC OXYGEN.

TWO NOTES ADDRESSED TO THE ACADEMY OF SCIENCES.

BY T. L. PHIPSON.

Translated by Chief Engineer Isherwood, U. S. Navy.

First Note. *Comptes Rendus,* 1893, p. 309.

I ask permission to present to the Academy the results of some experiments made during the last few years, relative to the chemical composition of the terrestrial atmosphere.

That the primitive atmosphere did not contain free oxygen may be accepted as certain, since sulphur and graphite —combustible substances—are found in the primitive rocks. Dr. Koene, who was for many years Professor of Chemistry in the University of Brussels, says that after the period of intense heat had passed, the atmosphere contained only nitrogen and carbonic acid, the proportions of which gradually diminished as the proportion of oxygen gradually increased.

I desired to ascertain how the plants of the present time were affected in an atmosphere of nitrogen gas, in an atmosphere of carbonic acid gas, in an atmosphere formed by a mixture of these two gases, and in an atmosphere of hydrogen gas. The experiments were made on plants of the genera Poa, Agrostis, Trifolium, Myosotis, Anthirrhinum and Convolvulus. Of all these plants, the Convolvulus arvensis is the best adapted for this kind of experiment, be-

cause of the smallness of its size and the rapidity of its growth.

I have elsewhere (*Chemical News*, 1883) stated ten years ago that microscopic plants (Protococcus pluvialis and P. palustris) vegetating in spring water can be transformed, so to speak, into veritable generators of oxygen gas.

My observations relative to this interesting subject have been published in the *Chemical News*, of London (June and July, 1893). In these experiments the roots of the plants—immersed either in a fertile soil or in water containing free carbonic acid, and thus exposed to all the substances necessary for vegetating—were kept in the dark, while the upper part of the plant was exposed to a northern light in a graduated inverted glass bell. The daily temperature varied during the experiments from 15° to 26° C.

I ascertained that the plants could live in carbonic acid, but they did not in the least thrive. In hydrogen the vegetating was less backward, but the hydrogen was gradually absorbed (burned by the oxygen secreted by the plant), and after a few weeks it had nearly disappeared. In nitrogen the Convolvulus arvensis can live a long time if the water employed in place of a rich soil is kept supplied with free carbonic acid. In a mixture of two-thirds nitrogen and one-third carbonic acid, the vegetation thrives well, and the composition of the atmosphere resulting after several weeks closely resembles that of our own, and without change of volume.

If the primitive ages of the globe be considered, there must be conceded, and many scientists do so concede, that the high temperature then existing would have prevented the formation of any chemical compound whatever, the matter of the globe being at that time in the state of free atoms; but in measure as the earth cooled, the elements combined according to the laws of chemical affinity, until, finally, the surface of the earth remained covered by an atmosphere of nitrogen gas only, a substance having no tendency to combine directly with other substances. Now, into this primitive atmosphere of nitrogen gas, vegetables have discharged oxygen gas during an incalculable period

of time, until the air has attained its present composition. The oxygen of our air is thus a result of vegetable life (which latter had necessarily to precede animal life). The carbonic acid gas appropriated by the vegetables must be regarded as a volcanic production.

The primitive atmosphere of nitrogen gas was, without doubt, and owing to volcanic action, richer in carbonic acid than the atmosphere of the present day.

Second Note. *Comptes Rendus*, 1894, p. 444.

Since the publication of my first note (*Comptes Rendus*, 1893, p. 309) I have made a number of new observations, which I have now the honor to place before the Academy.

In my first note I assumed the primitive atmosphere of the earth to have been composed principally of nitrogen, a gas which has only slight tendencies to combine with other substances; and that volcanic action supplied carbonic acid to the land, to the water and to the atmosphere.

Into this atmosphere of nitrogen, carbonic acid and aqueous vapor, the primitive plants discharged oxygen gas, the relative quantity of which has continuously increased from the first appearance of vegetable life.

My experiments, made with a great number of plants of the present day, vegetating in an artificially prepared primitive atmosphere, show that these plants are essentially anærobic; that is to say, they can live without free oxygen. Thus, the Convolvulus arvensis, for example, vegetating during three months in an atmosphere composed of humid nitrogen and a certain proportion of carbonic acid, converted this atmosphere into oxygenated air such as exists to-day; and if the experiment be continued sufficiently long, the air in my graduated inverted bells becomes richer in oxygen than our present atmosphere.

The first plants which appeared upon the land and in the waters of the earth were the inferior ones. Now, my experiments show that these inferior plants, these Protococcus, Conferva, Ulva, etc., discharge, weight for weight, much more oxygen in a given time than the superior ones. For example, I found that in one experiment the unicellular

Algues gave at least five times more oxygen than the avicular Polygonum.

It may easily be conceived that in measure as the anærobic cellule of the primitive plants was immersed in an atmosphere continuously becoming richer in oxygen, this cellule underwent continuous modification, until at the end of cycles the ærobic cellule was finally produced, a cellule which discharges carbonic acid instead of oxygen into the atmosphere. In this manner I explain the slow and gradual production of animal life.

My researches on this subject have been published in the *Chemical News*, of London, during the years 1893 and 1894 (4 volumes). In this note I can give only a mere sketch of the new theory to which my observations have led me. These publications had, for object, the following:

(1) That in the remotest geological periods, nitrogen formed, as it forms to-day, the principal part of the earth's atmosphere.

(2) That the presence of free oxygen in this atmosphere is wholly due to vegetation; and that the primitive plants were the means employed by nature to supply the air with that gas.

(3) That the plants of the present day, like those of the oldest geological evolutions, are essentially anærobic.

(4) That in measure as the proportion of free oxygen in the atmosphere continuously increased during the course of cycles, the anærobic cellule became less and less anærobic (mushrooms, ferments, bacteria), and finally completely ærobic (animal life).

(5) That even at the present time the most inferior unicellular Algues give, weight for weight, much more oxygen to the atmosphere than the superior plants.

(6) That in measure as the proportion of free oxygen in the atmosphere has continuously increased during the past long geological ages, the nervous cerebro-spinal system, the highest characteristic of animality, has continuously developed as paleontological investigations show.

BALZER'S DEVICE FOR MAKING MILLING-CUTTERS.

[*Being the report of the Institute, through its Committee on Science and the Arts, on the invention of Stephen M. Balzer.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 28, 1896.

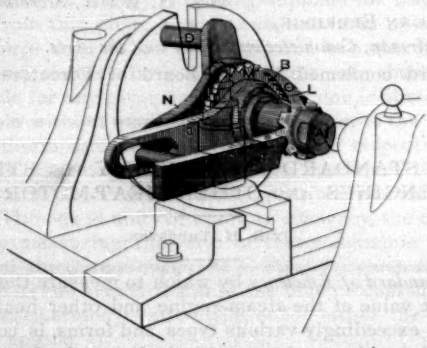
The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating Balzer's device for making milling-cutters, reports as follows:

This device is an apparatus designed to be mounted between the centers of an ordinary lathe for the purpose of forming and at the same time backing off the teeth of milling-cutters.

As shown in United States letters-patent No. 535,127, dated March 5, 1895, issued to S. M. Balzer, copies of which were submitted by the applicant, it may be briefly described as follows:

A steel spindle, with a recessed center at each end to receive the centers of the lathe, and a projecting arm provided with a pin to engage the slot in the face-plate, carries a hollow steel spindle or sleeve, which is provided with collars and clamp-nuts to hold the cutter blank to be operated upon. The center recesses at the ends of the spindle are placed eccentric to its axis, so that when the spindle is rotated the sleeve carrying the cutter, if prevented from rotating, is given a lateral motion to and from the tool-post. This sleeve is provided with a gear-wheel, fixed to it at the end next the face-plate, and also carries a similar gear-wheel mounted loosely upon it and in contact with the first wheel. These are differential wheels, the first having, say, sixty teeth, and the second, say, fifty-six teeth. Meshing with both these wheels is a pinion carried on a projection of the pin that engages with the face-plate. The second, or loose wheel, is prevented from turning by a projecting arm resting on the tool-rest.

The result of this arrangement is that when the lathe is set in motion, the revolution of the pinion around the two differential wheels causes the wheel fixed to the cutter-sleeve to make a part of a revolution, while the eccentricity of the spindle causes the sleeve and cutter to move toward the tool-post at the same time. A hardened steel shaping tool being firmly fixed in the tool-post, the result is a cut off the top or back of the tooth, gradually going deeper as the cutter advances. The cutter then recedes and advances again at the next revolution of the lathe for the next tooth. The degree of rotation of the cutter is determined by the relative number of teeth in the differential wheels, and may



be varied at pleasure by changing the wheels. It was found in practice that the unavoidable back-lash in these wheels caused the forming tool to chatter objectionably, and to avoid this a ratchet-wheel was substituted for the fixed wheel and a lever and pawl for the loose wheel. The result is entirely satisfactory, the machine working with great steadiness and precision. A number of practical tests were made with uniformly good success. The teeth made in this way may be sharpened by grinding on their faces without in the least altering their shape, until they are entirely worn out, and in this and other respects they are fully equal to cutters made by the expensive special

machines in general use. There is no other such device on the market, so far as is known.

The claim of the inventor of having produced a "cheap and effective device, capable of use in an ordinary lathe, by means of which milling-cutters or similar tools may be readily made," is fully borne out; and for the ingenuity and skill displayed therein, the Franklin Institute recommends the award to Stephen M. Balzer, of New York City, N. Y., of the John Scott Legacy Premium and Medal.

Adopted at the stated meeting of the Committee on Science and the Arts, April 8, 1896.

JOSEPH M. WILSON, *President.*
WM. H. WAHL, *Secretary.*

G. MORGAN ELDRIDGE,
Chairman, Committee on Science and the Arts.

Award confirmed by the Board of Directors of City Trusts.

THE STANDARD OF EFFICIENCY FOR STEAM-ENGINES AND OTHER HEAT-MOTORS.

BY R. H. THURSTON.

A Standard of Efficiency by which to measure the thermodynamic value of the steam-engine and other heat-motors, in their exceedingly various types and forms, is constantly required by the engineer, and the general adoption of a common and correct standard is one of the desirable conventions in all thermodynamic work. A number of standards, in themselves accurate and scientifically available and acceptable, have been proposed, and the question to be settled by common consent is: What one of the various possible standards shall be adopted?*

The Essentials of a Satisfactory Standard are:

(1) Ideal perfection and accuracy.

(2) Invariability under the conditions of its employment.

* See paper by Capt. H. R. Sankey, "The Thermal Efficiency of Steam-Engines;" Proc. B. Inst. C. E., March 24, 1896, p. 182.

(3) Convenience.

(4) Special suitability to the class of values which it is to measure.

Where, as is often the case, a number of possible standards are available, all having a common measure and fixed relations among themselves, that one will be chosen which presents the best combination of precise measures for use in the class of problems to which it is to be applied.

Heat-Engines, of whatever class, type or form, are employed simply to convert thermal energy into useful dynamic energy, and their efficiency is therefore measured by the ratio of the amount of energy thus rendered available to the quantity of energy originally supplied for transformation. From this point of view two measures of efficiency are at once seen to be available, and two standards are offered for choice. Both of the latter are absolute and invariable for any given case; but only one is absolute and invariable without qualification. The latter is the measure of the thermodynamic equivalent of the respective energies; the other is the measure of the maximum ideal conversion-ratio of the most perfect possible thermodynamic cycle. The one is unity of absolute efficiency, the other the quantity measuring the ratio of thermodynamic transformation of the Carnot cycle, $(T_1 - T_2) / T_1$, which ratio may be taken as the standard and as the unit of comparison for any other thermodynamic cycle, or for either the ideal or the real engine.

Efficiency Unity, taken as a Standard, infers complete transformation of all heat supplied into mechanical energy, *i. e.*, for example, perfect thermodynamic conversion of the British thermal unit of energy into 778 foot-pounds of dynamic energy, or 427 kilograms per calorie. It is in this measure that the efficiencies of the Carnot, as of all purely thermodynamic, cycles is measured. Thus gauged, the Carnot cycle, for example, within the usual maximum range of temperature of our steam-engines to-day, has an efficiency of about 30 per cent. This is evidently available as the ultimate and the universal standard for all thermodynamic operations.

The Carnot Efficiency, taken as a Standard, gives a measure of the economic relation of any thermodynamic cycle to the maximum ideal efficiency of all heat-engines, whatever the character of the working fluid adopted. It may be taken as unity in such cases, and the relation thus gauged is as absolute and accurate as the preceding, within its defined limitations. It permits the comparison of the measured efficiency of any heat-engine with that of the perfect engine within similar temperature range. It must obviously be carefully distinguished from the standard of perfect thermodynamic transformation-efficiency, unity. The Carnot Efficiency is a standard proposed and advocated by many authorities. It is not an absolute standard in a proper sense, since its limits are not fixed.

The Efficiency of any Chosen Ideal Thermodynamic Cycle is a standard adopted in many cases, and occasionally advocated as the unit of reference. It measures, when thus taken as the unit of efficiency, the relation of the thermodynamic effect of the real to that of the ideal engine, showing the degree of approximation of the machine as operated to its ideal representative—the perfect engine, working in the stated cycle. This is a standard employed by Rankine and by Clausius.

For example, comparing the efficiency of the best modern steam-engine employing saturated steam, about 0·20, with the Rankine cycle, which is that ideal cycle which constitutes the closest approximation to its method of steam distribution, the ideal case giving an absolute efficiency, 0·25, it is found to have, measured by this latter standard, a relative efficiency of 80 per cent.; while, compared with the Carnot cycle, the figure becomes about 70 per cent.

Absolute and Relative Efficiencies must thus be explicitly distinguished, and it would seem desirable that all other so-called efficiencies than the first of this series should be denoted by the latter term. The efficiency relative to the Carnot, or to the representative Rankine, or other ideal thermodynamic cycle, if properly defined, often proves a valuable datum in comparing the actual with the ideal performance of engines for the purpose of ascertaining how closely

the performance of the engine, under test or in regular use, approximates the perfect thermodynamic action of the same machine, all its extra thermodynamic wastes being extinguished. The degree of this approximation measures the range and the limit of possible further improvement.

This standard of efficiency thus is seen to have its own special purpose and use. *The absolute efficiency* of any engine is a measure of the proportion in which thermal energy supplied is converted into work, and permits the comparison of various ideal or real available cycles. *The relative efficiency* measures the degree in which the actual performance in the chosen cycle approximates the purely thermodynamic ideal maximum for that cycle; the difference between the real and the ideal indicating the limiting range of possible further improvement and the degree of imperfection of the machine, as such.

Each of these several efficiencies measures a valuable datum, and, in fact, no investigation is complete in which a determination is not made of each: of the absolute efficiency, as measuring the proportion of work obtained from the supply of energy delivered to the engine; of the relative efficiency, the Carnot cycle taken as a standard, as measuring the approximation to a most perfect ideal heat-engine; and of the relative efficiency of the representative steam distribution, as the Rankine or other, as given by the valve-motion employed, and assuming a non-conducting cylinder —as measuring the approximation to perfection in the adopted cycle. Each has its use, and neither can be thrown out as superfluous.

The absolute standard, Joule's equivalent of thermodynamic conversion, is the limit of perfect transformation; the Carnot cycle is the gauge of limiting thermodynamic transformation in the most perfect possible heat-engine cycle; the type and representative cycles of Rankine and Clausius gauge the limits of perfection of the classes of engine which, by their construction, must work in one or another of those particular kinematic and physical cycles.

It is now proposed to study, in some detail, each of these now generally accepted typical cycles, and the several

efficiencies of these cycles, taken as standards with which to compare the real engine.

The Carnot Cycle, representing, as it does, the extreme limit of possible economy in the operation of the heat-engine of whatever kind, and having the same value for similar ranges of temperature, irrespective of the nature of the working fluid, furnishes a standard which was shown by Carnot himself to be that with which all actual cycles and the performances of all real engines should be compared, to ascertain what is the degree of their perfection or their imperfection.* Improvements of the steam-engine, from the earliest days of the modern Watt engine to the present time, have had for their purpose and as their result the widening of the range of adiabatic expansion, and the restriction of extra-thermodynamic wastes. This means the closer approximation of the cycle and the physical conditions affecting the operation of the machine to those ideal conditions pointed out by the great "founder of thermodynamics," thus bringing the final efficiency of the engine to coincide as closely as practicable with these maxima of the Carnot cycle of similar temperature-range.

The writer has been interesting himself in the computation of these ideal maxima, and has, in the earliest of the succeeding paragraphs, assumed those limits of temperature which were primarily taken by Rankine for his computations of other cases; the purpose being to secure a standard of comparison that should complement the earlier work. Modern steam-engines, by attaining a better vacuum and lower temperature-limit on the one hand, and by the employment of high-pressure steam, and by thus gaining a correspondingly higher limit at the other end of the temperature-range, actually attain these ideal figures and a still higher ideal standard. The latter are discussed later.

The Steam-Engine Working in the Carnot Cycle has, obviously, the same efficiency as any other heat-engine operating in the same cycle within the same temperature-range.

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* Carnot's "Reflections on the Motive-Power of Heat," Thurston's translation, p. 68. New York: J. Wiley & Sons.

The value of this efficiency is always $(T_1 - T_2) \div T_1$, and the figures given in the tables herewith are the same for all working fluids when the values of T_1 and T_2 are the same. In the computations, the results of which are here tabulated, it is assumed that the terminal pressure, p_2, and the back pressure, p_3, are identical, as prescribed by Carnot, and equal, respectively, in the cases paralleling the condensing and the non-condensing engine of the common type of cycle to 4 and 18 pounds per square inch, absolute. Pressures are taken from 300 pounds, absolute, downward. The steam is assumed to be initially dry and saturated. Values are computed for the ratio of expansion r, the mean effective pressure p_e, the efficiency E, the B.T.U. expended per horse-power per hour, and the weight of steam and of fuel demanded per horse-power per hour, each pound of fuel being assumed to supply 10,000 B.T.U. to the steam. The volume traversed by the piston per minute per horse-power is also computed and tabulated. These "ideal efficiencies" and data represent those limits which may be approached by the "real engine," but never actually attained. It is probable, judging from experience already had, that they may be taken as representing about one-half better work than can be expected in even the best practice of the best builders, the same limits of pressure and temperature being assumed.

The methods adopted in these computations are those original with Rankine, and similar to those applied by him to his special cases of the non-conducting cylinder and the ideal jacketed engine.* The following are the symbols and formulæ:

Carnot Cycle.

p_1 = initial pressure in pounds per square foot, absolute.
p_2 = pressure at the end of expansion.
= back pressure. Expressed in pounds per square foot, absolute.

* "Steam Engine," Chap. IV, p. 104, *et seq.* Thurston's "Manual," Chap. V, Vol. I.

v_1 = initial volume.

= volume in cubic feet of 1 pound of dry and saturated steam at initial pressure.

[Take from steam-tables.]

v_2 = volume in cubic feet at the end of expansion =

$$\frac{1}{\frac{d p_2}{d T_2}} \left[J \log_e \frac{T_1}{T_2} + v_1 \frac{d p_1}{d T_1} \right]$$

$$= v_1 \left(\frac{p_1}{p_2} \right)^{.881}; \text{ where } .881 = \frac{1}{1.135}, \text{ nearly.}$$

T_1 = absolute temperature in degrees F., corresponding to p_1.

[Add 461° to the temperature given in steam-tables.]

T_2 = absolute temperature in degrees F., corresponding to p_2.

L_1 = latent heat of evaporation, corresponding to p_1.

[Take from steam-tables.]

r = ratio of expansion.

$$= \frac{v_2}{v_1}.$$

H_1 = heat expended per pound of steam, expressed in foot-pounds.

$$= J L_1.$$

J = 778.

$$\text{Efficiency} = \frac{T_1 - T_2}{T_1}$$

U = net work done per pound of steam, expressed in foot-pounds.

$$= H_1 \times \text{Efficiency}.$$

$$\text{M.E.P.}' = \frac{U}{v_2} \text{ in pounds per square foot.}$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144} \text{ in pounds per square inch.}$$

A = B.T.U. per I.H.P per hour.

$$= \frac{2545}{\text{Efficiency}}.$$

B = pounds of steam per I.H.P. per hour for efficiency unity.

$$= \frac{1980000}{H_1}.$$

C = pounds of steam per I.H.P. per hour for actual efficiency.

$$= \frac{B}{\text{Efficiency}}.$$

W = equivalent "water-rate" from and at 212° F.

$$= \frac{A}{966{\cdot}069}.$$

F = pounds of fuel per I.H.P. per hour, at 10,000 B.T.U per pound, net.

$$= \frac{A}{10000}.$$

D = piston displacement per I.H.P. per hour.

$= C v_2$ cubic feet.

D' = piston displacement per I.H.P. per minute.

$$= \frac{D}{60}.$$

The process of determination of the values of work performed per unit weight of steam, or weight of steam per horse-power per hour, of the work per stroke of engine, of the mean pressures, and of the efficiencies and the weights of steam and of fuel, and the quantity of heat required in B.T.U. to perform the work computed, are, in brief, as follows:

The unit weight, in this case 1 pound of water, enters the steam cylinder at initial maximum temperature and pressure and in the liquid state. It expands into steam at constant pressure and temperature, receiving from the source of heat its latent heat of vaporization, and it presently becomes one unit-weight of steam in the dry and saturated state. At this point the heat supply ceases, and adiabatic expansion commences, converting stored heat energy into

work until the lower limit of temperature and pressure is reached, and the maximum volume of the cycle is attained. The piston is next driven back, compressing the fluid, gradually and isothermally, into smaller and smaller volume, until, at such point as is indicated for the cycle, compression becomes adiabatic, and both pressure and temperature commence rising, the line finally terminating at the point at which the cycle was begun. The fluid is now once more a mass of water, and in precisely the same physical condition as to pressure, volume and temperature as at the start. The thermodynamic as well as the kinematic cycle is complete.

During this process it is evident that, taking the cycle as a whole, neither gain nor loss of sensible heat has occurred, and all work performed must have been done by conversion of latent heat of vaporization from the thermal to the dynamic form of energy. Also, since all heat received is absorbed at the maximum temperature, and all rejected is discharged at the minimum temperature, this is a Carnot steam-engine cycle, and its efficiency must be $(T_1 - T_2) / T_1$, as in every Carnot cycle, whatever the nature of the working fluid and whatever the temperature and pressure limits. This may be readily shown, also, by detailed computations of the quantities of heat and of work, step by step, in the cycle.

In illustration of the quantities obtained in this form of the "ideal case," let it be assumed that we desire to ascertain the degree to which heat-conversion may be carried in such a cycle in a case corresponding to that of the common non-condensing engine, taking initial pressures at intervals up to 300 pounds per square inch, absolute, and a common back-pressure at 18 pounds, for the type representing the non-condensing and 4 pounds for the condensing engine. It is required to find the pressures, volumes, temperatures, work performed and efficiencies. The steam-tables are relied upon for the measures of temperatures, pressures and latent heat. The accompanying figure presents, in graphical form, the resultant figures.

Computations being made for the case in which the Carnot

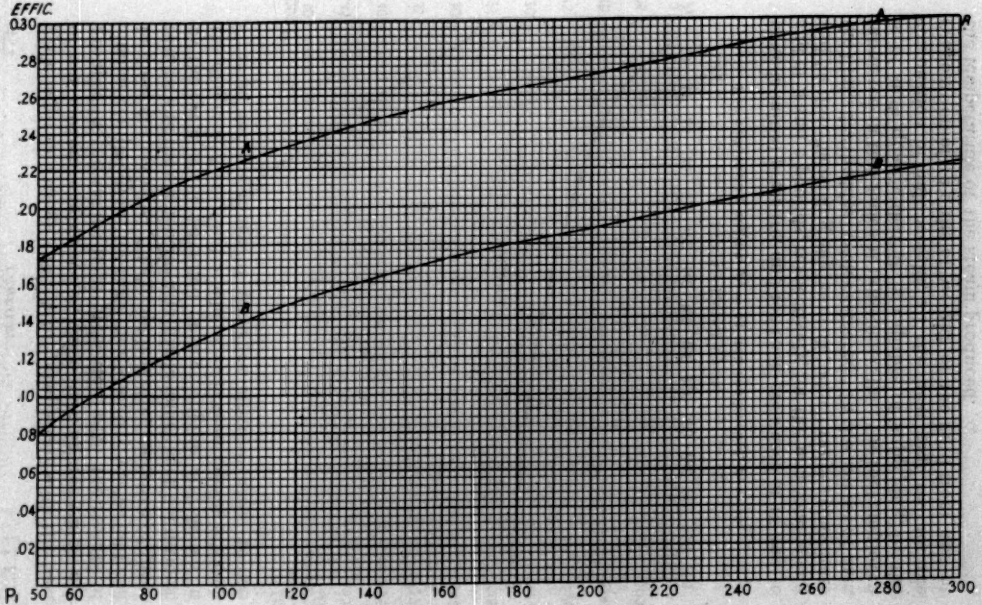


FIG. 1.—Carnot Cycle. For condensing engine, $p_2 = 4$; non-condensing, $p_2 = 18$.

cycle is given a range suitable for comparison with the best of our modern engine-cycles, we obtain figures which are grouped in the tables later presented, with the results of similar computations for the other standard cycles adopted in these discussions. The graphical representation of these results, and the efficiencies attainable under such conditions, by the cycle of the so-called perfect engine, are shown in the diagram, *Figs. 1* and *2*, where, as is seen, curves are constructed for the range of pressure already taken, to 300

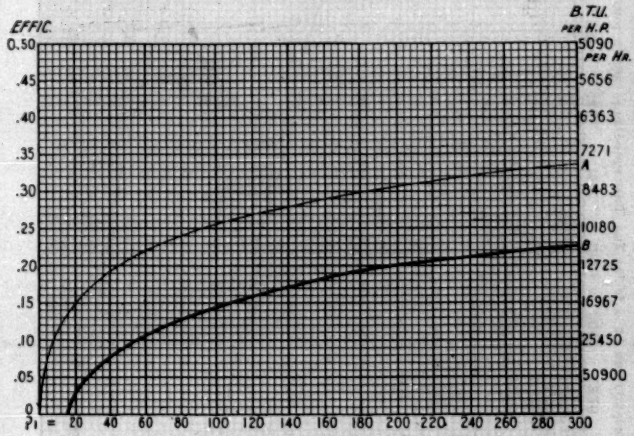


FIG. 2.—Carnot Cycle.

For condensing engine, $p_2 = 2$; non-condensing, $p_2 = 16$.

pounds initial pressure, and for back-pressures of 18 and 16 and of 4 and 2 pounds, respectively, for the non-condensing and for the condensing engine cycle, which ranges constitute the limits for the ideal cycles selected. In the last set of data tabulated in this series, it is assumed that the fuel employed is of such quality that it is capable of supplying, by the combustion of unit weight, all the heat required for the evaporation of 12 units of weight of the fluid from and at the temperature of the steam produced.

The Rankine Cycles, taken as Standards, permit the computation of the quantity of heat, steam, and fuel of a stated quality, which would be demanded by the ideal engine, by a steam-engine working in such a cycle and free from extra-thermodynamic wastes, such as invariably reduce enormously the efficiency of the real engine. Comparing the real engine with its ideal representative, it becomes possible to determine the nature and extent of its wastes and the method to be pursued in the endeavor to improve the machine as a thermodynamic engine. There are usually studied two cycles, originally discussed by Rankine—the adiabatic Rankine cycle and the Rankine cycle for steam retained dry and saturated.

The Rankine Adiabatic Cycle is the ideal toward which the common Corliss engine approximates most closely, a cycle which is characterized by variation from the Carnot by incomplete adiabatic expansion and by absence of clearance and compression. The steam enters the engine at boiler pressure, is expanded adiabatically—the cylinder being assumed to be non-conducting—is exhausted from a terminal pressure exceeding the back-pressure, and is completely rejected from the system at a constant back-pressure. The heat supplied is that required to raise the temperature of the feed-water from that of supply—as a maximum from that of the rejected fluid—and to vaporize it at the boiler pressure and temperature. In this respect, the case differs from that of the Carnot cycle, which demands only the supply of the latent heat of vaporization. The rigidly thermodynamic process here illustrated is the following:

Steam is produced by raising the temperature of a mass of feed-water, constituting one charge and acting as the vehicle of the heat acting in a single cycle of the engine, to that of the steam at boiler-pressure, and vaporizing it at that temperature and pressure. Unity of weight being assumed as a single charge, this amount of steam is introduced at boiler-pressure; adiabatic expansion occurs from initial to terminal pressure; reduction of pressure takes place at constant volume until back-pressure is reached;

reduction of volume then occurs at constant pressure until, the quality constantly changing, the fluid becomes entirely liquid—and the cycle is complete.

The Steam-Engine Working in the Rankine Adiabatic Cycle experiences not only the loss of thermodynamically rejected heat, as does the Carnot the minimum possible loss, but also loses efficiency by its incomplete expansion and by its omission of the adiabatic and complete compression of the "dynamic feed-water heater." Thus, while the Carnot cycle serves to determine the total of all wastes, when the work of the actual engine is compared with it, that of Rankine serves the especial purpose of exhibiting the wastes of the real steam-engine having such a steam distribution as may be taken to be fairly represented, in the ideal case, by this cycle. It shows what gains remain to be effected in such a type of engine by extinction of wastes due to the non-adiabatic character of the operation.

In the cycle computed—and of which the figures are given in the appended tables—it is assumed that the terminal pressures are 7 pounds per square inch absolute, and 21 pounds, respectively, for the condensing and the non-condensing engines. The back-pressures are taken at 2 and at 16 pounds.

The comparison of the two preceding ideal cycles shows what may be gained by change of the design of the engine and of its valve gear in such manner as to reproduce the as yet unattained cycle of the "perfect engine of Carnot." The relative efficiency of the real engine-cycle and the ideal of Rankine measures imperfections of the extra-thermodynamic conditions of operation of the engine; the relative efficiency of the Rankine and the Carnot ideal cycles measures the defects of the thermodynamic action of the machine.

The Method of Computation is briefly as indicated in the following summary:*

Rankine's Adiabatic Engine-Cycle.

v_1 = volume in cubic feet at point of cut-off.

* Thurston's "Manual of the Steam Engine," Vol. I, § 116.

= initial volume = volume of 1 pound of dry and saturated steam at the pressure chosen.

[Take from steam-tables.]

v_2 = volume at end of expansion.
$= v_1 r$.

r = ratio of expansion.

[In no case expand below back-pressure.]

p_1 = initial pressure in pounds per square foot, absolute.

p_2 = pressure at the end of expansion, expressed in pounds per square foot, absolute.

$$= p_1 \left(\frac{v_1}{v_2}\right)^{1.135}$$

p_3 = back-pressure in pounds per square foot, absolute.
$= 2 \times 144 = 288$ pounds per square foot for condensing engine.
$= 16 \times 144 = 2{,}304$ pounds per square foot for non-condensing engine.

J = 778· foot-pounds per degree F.

T_1 = absolute temperature in degrees F., corresponding to p_1.

[Take temperature from steam-tables and add 461°.]

T_2 = absolute temperature in degrees F., corresponding to p_2.

T_4 = absolute temperature in degrees F. of feed-water.
$= 104 + 461 = 565°$ F., for condensing engine.
$= 210 + 461 = 671°$ F., for non-condensing engine.

λ_1 = total heat of evaporation, corresponding to p_1, in B.T.U.

[From steam-tables.]

q_4 = heat in feed-water at T_4, in B.T.U.
$= T_4 - (461 + 32)$.

U = net work done per pound of steam (in foot-pounds).

$$= J\left[T_1 - T_2\left(1 + log_e \frac{T_1}{T_2}\right)\right] + \frac{T_1 - T_2}{T_1} H' + v_3(p_2 - p_3).$$

L_1 = latent heat of evaporation, corresponding to p_1, in B.T.U.

[From steam-tables.]

H' = same in foot-pounds = $J L_1$.

H_1 = heat expended per pound of steam, in foot-pounds.
$= J(\lambda_1 - q_4)$.

$$\text{Efficiency} = \frac{U}{H_1}.$$

$$\text{M.E.P.}' = \frac{U}{r\, v_1} = \frac{U}{v_2} \text{ in pounds per square foot.}$$

$$\text{M.E.P.}'' = \frac{\text{M.E.P.}'}{144} \text{ in pounds per square inch.}$$

A = B.T.U. per I.H.P. per hour.

$$= \frac{2545}{\text{Efficiency}}.$$

B = pounds of steam per I.H.P. per hour for efficiency unity.

$$= \frac{1980000}{H_1}.$$

C = pounds of steam per I.H.P. per hour for actual efficiency.

$$= \frac{B}{\text{Efficiency}}.$$

W = equivalent "water-rate" from and at 212° F.

$$= \frac{A}{966{\cdot}069}.$$

F = fuel per I.H.P. per hour.

$$= \frac{A}{10000}.$$

D = piston displacement per I.H.P. per hour.
$= C\, v_2$ cubic feet.

D' = piston displacement per I.H.P. per minute.

$$= \frac{D}{60}.$$

The Rankine Cycle for Continuously Dry Steam, the cycle of the ideal jacketed engine, is defined as that in which, by the introduction of heat during the process of expansion, the con-

densation due the transformation of heat into work in the expansion period—discovered by Rankine and Clausius, independently and almost simultaneously—is prevented, and the working charge is thus kept dry and saturated throughout the forward stroke of the piston. It differs from the adiabatic cycle in the fact that heat is thus continuously passed into the cylinder, and into the working charge during the whole period of expansion, and thus the quantity of heat demanded per stroke is increased, the work performed is somewhat enhanced, while the efficiency is diminished in consequence of the fact that Carnot's principle is not adhered to, and heat is not all supplied at the higher limit of temperature, as is the case in the preceding form of cycle.

In this cycle, the steam is assumed to enter the engine dry and saturated, to expand with absorption of heat from the jacket, in precisely that quantity required to retain it in the dry and saturated state, and to describe the same lines on the diagram, during exhaust, as in the case of the adiabatic cycle of Rankine. The quantity of steam demanded in a cycle is the sum of that passing through the engine and that condensed at boiler-pressure in the jacket to supply the heat required to keep the charge dry. The quantity of heat supplied is that demanded for the production of both quantities of steam—the first from the temperature of the feed-water, the second from that of boiler-steam.

The Steam-Engine Working in the Second Rankine Cycle is assumed to at least approximate the ideal cycle. As stated by the author of this method of discussion, the absorption of heat by the steam is exceedingly rapid when moist, very slow when dry; and it may thus, as he states, be assumed that the condition of the steam in the engine is substantially that of the ideal case. Actually, however, as shown by innumerable engine-trials, even the most perfect jacketing does not produce precisely the condition assumed in the ideal case. Extra-thermodynamic wastes, usually, in good practice, not far from one-half the amount of those of the real engine, unjacketed, are observed. It is the difference produced by the remanent wastes, externally and inter-

nally, that measures the imperfection of the machine as a thermodynamic apparatus.

The ratio of the computed efficiency of the ideal engine to the observed and measured efficiency of the real engine constitutes a gauge of the excellence of the design and of its construction, such as makes this cycle a valuable standard for this special purpose; exactly as the Rankine adiabatic and the Carnot cycle each in its way serves as a special and useful standard. Here, as in the preceding case, the relative efficiency of the real in comparison with the Carnot cycle measures the total imperfection of the machine as a heat-engine; while the relative efficiency of this ideal cycle, as compared with the Carnot, gives a measure of the imperfection of the thermodynamic cycle adopted.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, held November 17, 1896.

DR. H. F. KELLER, President, in the Chair.

A NEW HIGH-TEMPERATURE FURNACE.

BY H. L. GANTT, A.B., M.E.

Until recently the difficulty of obtaining and controlling extremely high temperatures has kept us to a large measure in ignorance of the uses to which they may be applied. Within the last few years, however, the electrical furnace has thrown a flood of light on this subject, and we to-day realize that high as the temperature of the Siemens steel melting furnace and the blast furnace seems to be, temperatures far higher are destined to be extensively used in the arts at an early date.

Already the electrical furnace has been brought largely into play in the manufacture of aluminum and calcium carbide, and while we realize that electricity is a most efficient and convenient method of obtaining the necessary high temperatures, we must not lose sight of the fact that it is an exceedingly expensive one, and we feel bound to inquire

if even in the Siemens furnace we have exhausted all the possibilities of producing high temperatures by means of combustion. It is the object of this paper to inquire into this subject and to find out the possibilities that may lie in the field of a furnace producing a temperature from 1,000° to 2,000° higher than that of the Siemens furnace.

The actions carried on in the electrical furnace, and, in fact, all the actions we propose to study, are of a reducing nature, hence it is necessary that we have an excess of carbon present in our furnace, and, fortunately for our investigation, the highest temperatures obtainable by combustion can be gotten by burning carbon with hot air. Our furnace must then be on the order of a blast furnace, which, while producing a temperature amply high for the purpose of reducing iron from its ore, does not by any means attain the maximum temperature possible by the combustion of carbon.

To try to form some idea of what temperature we may be able to get, we had better consider a coke-fired crucible steel-melting furnace, blown with a cold blast. In such a furnace very soft steel can be melted and made perfectly fluid in about four hours, and that, too, in a pot, the walls of which have but poor heat-conducting power. As the temperature of such steel is about 3,000° F., it is safe to say that the fire reaches a temperature at least 1,000° higher, or about 4,000°.

It will be shown later that we can readily heat our air blast to a temperature of 3,000° F., and we have to ask—what temperature can be obtained with such a blast? If a cold blast will give a temperature of 4,000° F., a blast heated 3,000° ought to add just that much to the temperature of the fire, which would then be 7,000° F. We should not, of course, expect to realize all the benefit from the heat in the blast, but we may safely assume that we shall get two-thirds of it, and that our fire will reach the temperature of 6,000° F.

With regard to the possibility of obtaining a temperature of 6,000° F., there will undoubtedly be a difference of opinion; but so far, all our calculations have been based upon the assumption that the combustion takes place under a comparatively low pressure, but we may build our furnace

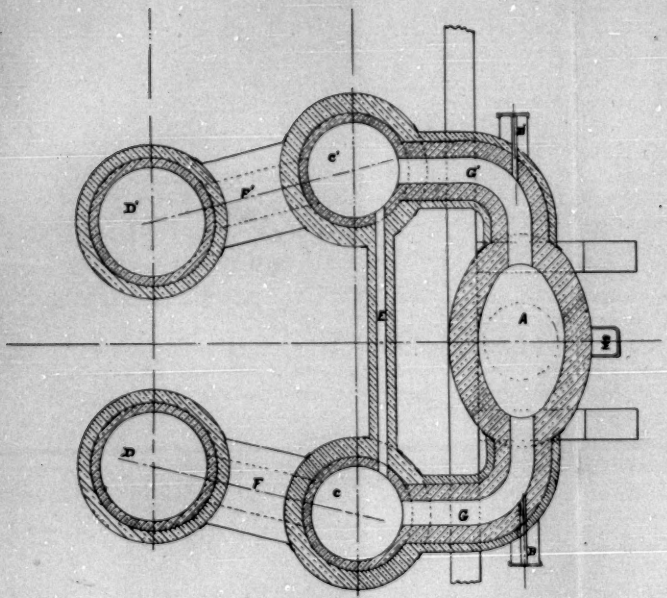


FIG. 2.—Section through *A B*.

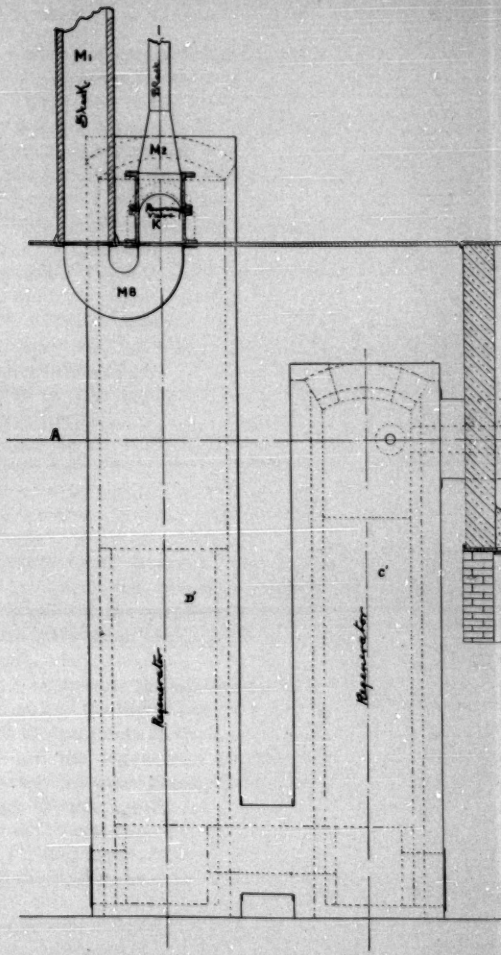
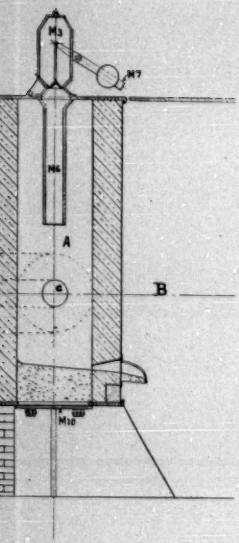
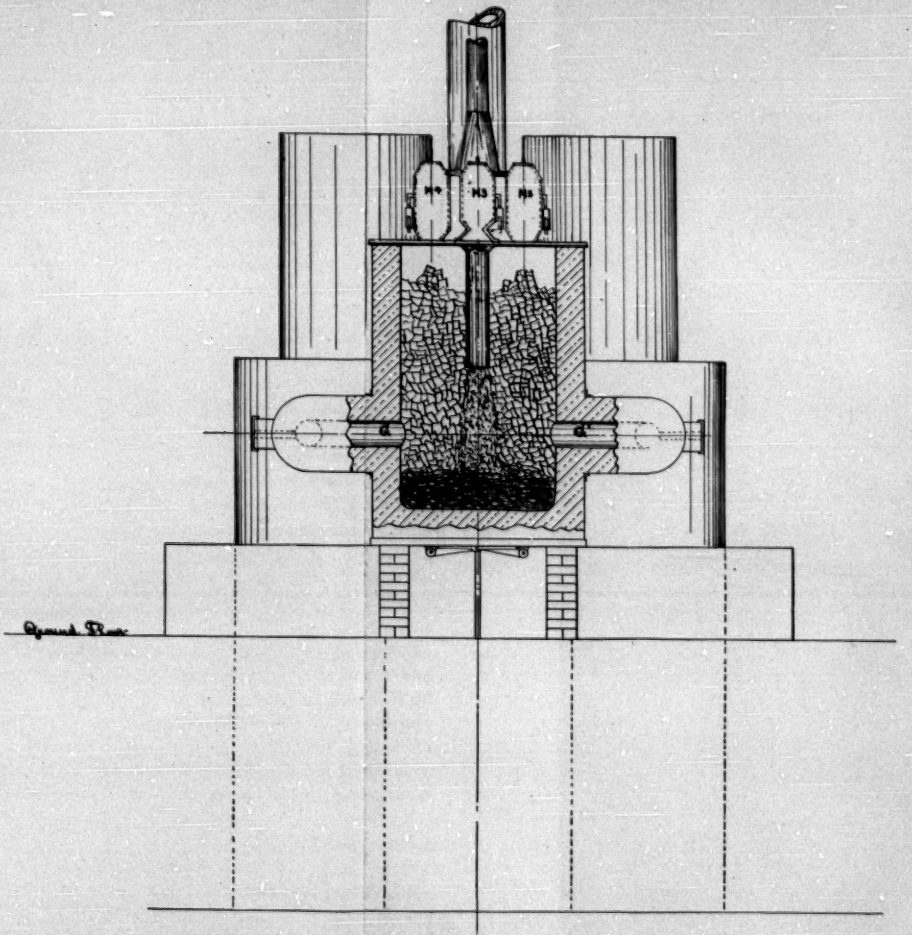


FIG. 1.

H. L. GANTT'S HIGH-TEMP





IPERATURE FURNACE.

FIG. 3.

in such a manner as to admit of our maintaining in it a pressure of one or more atmospheres, in which case the temperatures will be much higher, and in the furnace about to be described, the writer believes there will be no difficulty in obtaining a temperature of at least 6,000° F.

The furnace in question resembles the blast furnace, inasmuch as it is a shaft furnace fired with coke and blown through tuyeres, but differs from the blast furnace in the use of regenerators instead of hot-blast stoves. At the same time the regenerators are something more than is ordinarily included under that term, for in these chambers we complete the combustion of the blast furnace gases, in which respect they resemble somewhat hot-blast stoves. This, however, is as far as the resemblance goes, for the air used to complete this combustion in the regenerators is hot air, while in hot-blast stoves it is cold.

To obtain the conditions above enumerated, we build a Siemens regenerative furnace, which has for the combustion chamber a shaft to hold the fuel and charge and one set of regenerators. If we now connect these regenerators with each other by means of one or more passages near the top, the hot air will be divided into two portions, one of which will pass through the furnace, promoting combustion therein, and the other will pass directly to the outgoing regenerator and complete in there the combustion of the carbonic oxide in the gas to carbonic acid.

In the cuts herewith, A represents the combustion chamber, or furnace proper; G and G' the tuyeres, or flues through which the air enters and the products of combustion leave the furnace; C and C' are the regenerator chambers in which the secondary combustion takes place, the hot air for which is supplied through the passage E.

D and D' are simply additional regenerators, connected respectively with C and C', long regenerators of small cross-section being considered more efficient than shorter ones of larger sectional area.

K is a four-way reversing valve, through which the blast enters the furnace, and the products of combustion escape to the stack. The furnace proper is provided with three

hoppers, the center one for the material to be reduced and the other two for coke, which by this means is made to surround the charge entirely and protect it from any oxidizing action.

The temperature which we can obtain in this furnace evidently depends upon the temperature of our blast, which, in turn, depends upon that of the regenerators *C* and *C'*.

In order to consider what temperatures we may expect to get in these chambers, let us suppose the furnace to have a fire in the chamber *A*, but to be otherwise quite cool. If a blast be blown through *K*, *D*, *F*, *C* and *G*, we know we can in a short while get a temperature in *A* of from 3,500° to 4,000° F. The products of combustion escaping into *C'*, at the above temperature, will be further burned by the air passing through *E*, and it is safe to say that the chamber *C'* may be heated to the same temperature as the furnace. If, now, the direction of the blast be reversed, the temperature of the air going into *A* and through *E* will certainly be 2,000° F., and our furnace temperature will rise to perhaps 5,000° F., and the products of combustion, containing a large percentage of carbonic oxide, will reach the chamber *C* at a temperature but little lower. These, mingling with air at 2,000° F., will undergo further combustion, and, if they do not increase in temperature, will at least not cool much, and we may certainly expect to get the chamber *C* up to between 4,000° and 4,500° F. Upon reversing, we shall be able to get the air to a temperature above 3,000° F., which was the temperature we considered necessary to give us 6,000° F. in the furnace. As our furnace approaches 6,000° F. in temperature, our regenerators will probably approach 5,000° F., and there seems to be but little doubt that we shall be able to get a temperature as high as we desire, or at least as high as we can find materials to resist.

Having seen what temperatures we can probably obtain in a coke-fired furnace of the proper form, let us try to find out exactly what goes on in an electric furnace and make a comparison of the two sets of conditions.

The formation of calcium carbide in the electrical furnace by means of lime and coke was discovered by Dr. Borchers

about ten years ago. He seems to have investigated the subject quite carefully, and proved to his satisfaction what has since been demonstrated, that the action is not due to electricity, as such, but to the heat produced by it. A short account of his experiments is given in the *Engineering and Mining Journal* of October 14, 1895. More recently this method of manufacture has been put upon a commercial scale by Mr. T. L. Willson, and calcium carbide is said to be manufactured now in large quantities at Niagara Falls.

With regard to the temperature in the electrical furnace, M. Henri Moissan, *Comptes Rendus*, July–December, 1892, Vol. CXV, p. 1,031, tells us that at 3,000° C. (5,432° F.) carbon reduces oxide of calcium, and that the metal is liberated in abundance and unites with the carbon of the electrodes to form calcium carbide.

The difficulty of measuring or even estimating the extremely high temperatures of the electrical furnace is very great; but it is safe to say that the formation of calcium carbide being an endothermic reaction, the temperature of the furnace does not rise much above the point at which it goes on freely, for any heat over and above the amount necessary to maintain this temperature would undoubtedly go to promote chemical action rather than to cause a further increase of temperature, which is probably not very much above 5,500° F. These conditions are so nearly identical with those which our coke furnace promises, namely, a temperature of 6,000 ° F. and a strongly reducing action, that it would seem that any reaction produced in one furnace would occur in the other.

Further, Mr. Walton Clark, General Superintendent of the United Gas Improvement Company, of Philadelphia, is my authority for the statement that there is produced in the blast furnace a substance which, with the addition of water, will give off acetylene gas.

The railroad leading to Chestnut Hill, a suburb of Philadelphia, where Mr. Clark lives, is ballasted with blast furnace slag, and he has often perceived the odor of acetylene in passing over a piece of newly ballasted road after a rain. Knowing lime to be a constituent of the blast furnace

charge, it is certainly most probable that the carbide in the slag giving off acetylene when dampened is that of calcium. If now we grind together a mixture of lime and coke with a little tar for a bond to prevent waste of the ground-up material, and having dried it, charge it in small lumps through the center hopper of our furnace, we shall have conditions far more favorable for the formation of a carbide than can possibly occur in the blast furnace, and almost identical with those occurring in the electrical furnace.

Again, our furnace offers the most favorable conditions that have yet been contrived for the study of that most interesting of problems, the fixation of atmospheric nitrogen and the manufacture of cyanides. The manufacture of cyanides, and especially potassium cyanide, in small quantities in the blast furnace, has been long known, but the conditions most favorable have not been determined. The amount of work being done on the subject now, which is best illustrated by the number of British patents dealing with cyanides, ferrocyanides and sulphocyanides, published during the past ten years, a table of which is given below, indicates an early solution of the problem. The table is as follows:

1886.	*1887.*	*1888.*	*1889.*	*1890.*	*1891.*	*1892.*	*1893.*	*1894.*	*1895.*
4	5	2	4	4	5	7	12	15	33

At a meeting of the Society of Chemical Industry, January 8, 1896, Mr. James T. Conroy, B.Sc., Ph.D., presented a paper, entitled, "Some Experiments Relating to the Manufacture of Cyanides," which is published in the *Journal of the Society of Chemical Industry*, January 31, 1896, and reviews the work that has been done in this line. I give the following extracts from his paper:

"Professor Clark, in 1837, found the efflorescence occurring near the boshes of the Clyde blast furnaces, worked with hot blast, to consist chiefly of potassium cyanide. A similar phenomenon was found to occur in the Hartz, where the hot blast was used; and in 1843, Redtenbacher found it near the light-hole in the furnaces at Marianzoll, in Styria, where it has been produced in marketable quantities. In 1845, Bunsen and Playfair investigated the subject, and

found the zone of formation was just above the tuyeres. To estimate the quantity formed, they drilled a hole in this portion of the furnace and conducted the issuing gas into water. The analysis of the gas gave:

N	58·05
CO	37·43
H	3·18
CN	1·34

"As a result of his work, Bunsen proposed a special blast furnace for the production of cyanides, in which coke and potash were arranged in alternate layers and heated with a strong blast."

It does not appear, however, that such a furnace was ever built.

Continuing our extracts:

"Riechen then investigated the subject and found, under conditions in which only atmospheric nitrogen was present, that cyanides were formed, and he further showed that the temperature must be sufficiently high to produce metallic potassium and that the nitrogen gas should be previously heated.

"His experiments were confirmed by Delbruk.

"These facts having now been firmly established, many attempts have been made to found a working process upon them, and numberless patents, all very similar to each other, have been taken out, but none have proved commercially successful.

"The essential feature is conducting nitrogen (N), or, in the later processes, ammonia (NH_3), over a heated mixture of coke and potash, but the temperature of the formation of the cyanides is in all cases extremely high, in fact, so high as to kill the process, especially when ammonia is used, since this gas decomposes rapidly at the temperature employed."

As a practical confirmation of the above, the most recent patents on the subject specify an intimate mixture of potash (K_2CO_3) and carbon to be subjected to a high heat in the presence of ammonia or nitrogen, and further state that if nitrogen be used the temperature must be very high.

If through the center hopper of our furnace we drop a mixture of coke and potash, which have been thoroughly ground together with a little tar and then dried and broken into lumps, we can obtain these conditions almost perfectly, and the experiment of making potassium cyanide in this manner seems to be worth making.

The next question is—how are we to build a furnace that will withstand such temperatures? In order to resist the fluxing action of lime, the furnace must be lined with a basic material, and, luckily, the most refractory substance available is magnesite, which is basic. What temperature magnesite will stand when subjected to no fluxing action, we do not know, but we do know that it is much more refractory than lime. Again, in the hottest portion of the furnace the exposed surfaces of the magnesite brick will, undoubtedly, become covered with a coat of magnesium carbide, which will probably protect them somewhat. All things considered, it seems quite possible to get a lining to resist the temperature needed.

There are numerous other uses to which this furnace may be put, which are much less problematical than those just discussed, but as they lie in an entirely different line, they are foreign to the subject of this paper.

DISCUSSION.

DR. JOS. W. RICHARDS (Correspondence):—Mr. Gantt's proposed furnace is based on sound metallurgical principles. He would not, however, theoretically attain to the temperatures mentioned in his paper. The obtaining of refractory material to withstand temperatures between 2,000° and 3,000° C. is, furthermore, not so easy. Moissan has found in the electric furnace that at 2,300°–2,400° C. pure alumina melts to a limpid liquid; at 2,600°, magnesia becomes fluid; at 2,800°–3,000°, lime melts, especially in presence of carbon. The only remedy I can propose for this melting of the lining is a water-jacketed furnace, or, at least, water-jacketed around the zone of greatest heat, and then lined with magnesia. The rate of loss of heat would necessarily

be greater than with pure magnesia walls; but the melting would be checked within a certain distance of the water-jacket, and the lining thenceforth consist of chilled magnesia.

Regarding the theoretically attainable temperature—leaving conduction of heat out of the question, and considering merely the highest temperature momentarily attainable at the instant of combustion—I have made the following calculations:

Let the reaction be:

$$2C + O_2 = 2CO = + 57{,}280 \text{ cal.},$$

and the heat set free, calculated to 0° C., taken as 2,387 calories per kilo of carbon, based on Berthelot and Thomsen's best results. We must first calculate the heat of this combination at high temperatures (represented by t) in order to get the true quantity of heat developed in the furnace. This calculation is based on the principle of thermo-chemistry, that the heat of combustion at any temperature equals the heat of combustion at 0°, *plus* the heat capacity of the fuel and oxygen to that temperature, *minus* the heat capacity of the oxidized product from that temperature to 0°.

For these calculations we have the following data:

Heat in 1 kilo carbon at $t° = 0{\cdot}53\ t - 134{\cdot}6$ calories.

(For t over 1,000° C. calculated from Weber's results.)

Heat in 1 kilo oxygen at $t° = 0{\cdot}131875t + 0{\cdot}000057t^2$.

Heat in 1 kilo carbonic oxide $= 0{\cdot}1507t + 0{\cdot}000057t^2$.

(For t between 1,600° and 4,000° C.—Vielle and Berthelot.)

We therefore have:

Heat capacity of C_2 (24 kilos) $= 12{\cdot}72t - 3{,}230$ cal.
Heat capacity of O_2 (32 kilos) $= 4{\cdot}22t + 0{\cdot}0016t^2$ cal.
Heat capacity of $2CO$ (56 kilos) $= 8{\cdot}44t + 0{\cdot}0032t^2$ cal.

And, hence, for temperatures between 1,600° and 4,000° C.:

$$2C + O_2 = 2CO = 54{,}050 + 8{\cdot}5t - 0{\cdot}0016t^2 \text{ cal.}$$

However, since the temperature of the air used may vary, it will be more convenient to leave out of the above expression the heat capacity of the oxygen, and thus to obtain an expression for the heat generated at $t°$ by the combustion of carbon by cold air. If we further omit the heat capacity of 2CO, we will have the heat generated in the furnace, inclusive of the heat capacity of the product, down to 0° C. as a base. This expression is

$$2C + O_2 = 2CO = 54{,}050 + 12{\cdot}72t.$$

Having now an expression for the heat generated by the combustion with cold air, the next step is to calculate an expression for the heat capacity of the air used, in order that, if it be preheated, its sensible heat may be added to the heat generated by combustion, to obtain the total heat in the furnace.

The heat capacity of 1 kilo N $= 0{\cdot}1507t + {\cdot}000057t^2$.

$O_2 = 32$ kilos corresponds to $106\frac{2}{3}$ kilos of nitrogen.

Heat capacity of	$106\frac{2}{3}$ N	$= 16{\cdot}075t + 0{\cdot}0061t^2$.
Heat capacity of	32 O	$= 4{\cdot}22t + 0{\cdot}0016t^2$.
Heat capacity of air needed		$= 20{\cdot}295t + 0{\cdot}0077t^2$.

The final step is to calculate an expression for the heat capacity of the products of the combustion. These are:

Heat capacity of 2CO (56 kilos)	$= 8{\cdot}44t + 0{\cdot}0032t^2$.
Heat capacity of [N] ($106\frac{2}{3}$ kilos)	$= 16{\cdot}075t + 0{\cdot}0061t^2$.
Heat capacity of products	$= 24{\cdot}515t + 0{\cdot}0093t^2$.

Gathering these expressions together, we have:

Heat developed by the combustion	$= 54{,}050 + 12{\cdot}72t$.
Sensible heat of hot air	$= 20{\cdot}295t + 0{\cdot}0077t^2$.
Sensible heat of products of comb'stion	$= 24{\cdot}515t + 0{\cdot}0093t^2$.

Proceeding from these expressions, and making the assumption that the products of combustion contain, as sensible heat, the sum of the sensible heat in the preheated

air and the heat generated by combustion, we have the following deductions:

I. Air for combustion, cold—

$$24{\cdot}515t + 0{\cdot}0093t^2 = 54{,}050 + 12{\cdot}72t.$$

from which

$$T = 1{,}860^\circ \text{ C.}$$

This result is not very different from what we know can be obtained by charcoal and an air blast, by which platinum (melting-point, 1.775° C.) has been melted by Meyer; but it must be remembered that, in a shallow fire, carbon burns partly to CO_2, but that, in a furnace of any size, such can only be the case within a few inches of the blast nozzle, and that the body of the furnace probably approximates the temperature calculated above.

II. Air preheated to 730° C.

Heat in air $= 20{\cdot}295\ (730) + 0{\cdot}0077\ (730)^2 = 18{,}918$ cal.
Heat developed by combustion $= 54{,}050 + 12{\cdot}72t.$

Total heat in furnace $= 72{,}968 + 12{\cdot}72t.$

Whence

$$24{\cdot}515t + 0{\cdot}0093t^2 = 72{,}968 + 12{\cdot}75t.$$

and

$$T = 2{,}238^\circ \text{ C.}$$

I have chosen this temperature of air, because it is about the average of the hot-blast for a furnace producing grey iron, and on such a furnace LeChatelier has measured the temperature at the level of the tuyeres as 1,930° C. Since the absorption of heat by slag and iron, and by the expansion of the blast, were not considered in the calculation which gave 2,238°, the agreement may be considered fairly satisfactory.

III. Air preheated to 1,000°.

$$T = 2{,}400^\circ \text{ C.}$$

IV. Air preheated to 1,500°.

$$T = 2{,}735^\circ \text{ C.}$$

V. Air preheated to 2,000°.

$$T = 3{,}095° \text{ C.}$$

VI. Air preheated to 2,500°.

$$T = 3{,}470° \text{ C.}$$

VII. Air preheated to T°.

$$T = 9{,}000° \text{ C.}$$

The last result gives the theoretical temperature attainable by Mr. Gantt's process, pushed to its extreme limit, *i. e.*, with the incoming air preheated to the maximum temperature attainable in the furnace. Of course, it has only a theoretic interest, as showing the imaginary maximum. Practically, result V (air at 2,000° — furnace at 3,000°) gives what, I think, will be the maximum temperature which it will be possible to attain in an actual test, with the use of materials available, and with the minimum of burden on the fuel.

NOTES AND COMMENTS.*

A PROCESS FOR ELECTROLYTIC DESILVERING ARGENTIFEROUS LEAD.

D. Tommasi, in the *Engineering and Mining Journal*, describes the following mode of procedure:

The principle on which this procedure is founded consists in electrolyzing a lead solution, which not merely possesses an extremely weak electric resistance, but does not give rise to lead peroxide (PbO_2), and, in taking the argentiferous alloy itself as anode and cathode, a metallic disc which cannot be attacked by the bath.

Under the action of the current the lead of the anodes enters into solution, and is transferred, in the state of spongy crystals, upon the disc which serves as cathode, while all the silver contained in the lead, being insoluble in the bath, is deposited at the bottom of the vat in a perforated receiver destined for its collection.

The following is the course to be followed for the electrolytic extraction of silver from argentiferous lead:

We melt the lead and then cast it in moulds having the shape and the thickness which are intended for the anodes. This being done, we suspend

* From the Secretary's monthly reports.

each anode to one of the two metallic poles which are found placed about the upper part of the electrolyzer.

Each metal pole is fitted with an endless screw and with nuts. At the ends of these poles are fixed plugs intended to connect the anodes electrically among themselves, and to secure the whole to the positive pole of the dynamo.

The object of this arrangement is not merely to keep the electrodes at a determined distance from each other, but to approximate them if this distance becomes too great in consequence of the progressive wear of the anodes.

The disc which serves as cathode is placed between the two anodes, and communicates with the negative pole of the dynamo by means of a metal brush rubbing upon its axle.

The electrolyzer being fitted up, we pour in the bath (a solution of the double acetate of lead and sodium, or of lead and potassium), close the circuit, and cause the disc to revolve at the rate of one or two rotations per minute.

When the current is established, the lead begins to deposit upon the disc in the form of small, spongy crystals. When the deposit of lead has acquired a sufficient thickness, and it is thought suitable to remove it, the current is interrupted and the scrapers closed.

In consequence of their friction against the faces of the disc, the lead is detached and falls into sloping gutters, which bring it upon a sieve of metal cloth. The lead is drained, washed with distilled water and then submitted to a strong pressure.

The liquid which flows off is added to the washing-waters, and the whole evaporated down to 30° Baumé. When cold, this liquid is introduced into the electrolyzers by means of a pump. The compressed lead is heated on a crucible with 2 or 3 per cent. of charcoal in powder, and when melted it is cast in ingots.

When the anodes are dissolved, we may either replace them with fresh anodes, or merely withdraw the silver deposited at the bottom of the vat. In this latter case, we raise the disc by means of a windlass, then withdraw the perforated recipient placed at the bottom of the vat at the beginning of the operation; this contains all the silver left behind by the argentiferous lead of the anodes.

The silver, when collected, washed and dried, is melted in a crucible with sodium nitrate and a little borax, and is then cast into ingots.

METALLIC CARBIDES.

Among the many new fields of work opened up by the introduction of the electric furnace, according to *Nature*, is the preparation of difficultly-reducible metals undertaken with success by M. Moissan. These reductions being necessarily effected by the presence of carbon, the formation of definite metallic carbides of great stability soon became apparent, the properties of which came to be of such interest that their preparation was systematically attempted. Certain metals, such as gold, bismuth, lead and tin, do not

form carbides at the temperature of the electric furnace, neither do they dissolve any carbon. The metals of the platinum group dissolve carbon with facility and deposit the whole of it, on cooling, in the form of graphite, the metals being unchanged. Copper, silver and iron take up carbon in quantities, which, although small, are sufficient to cause marked changes in the physical properties of the metals; it is noteworthy that no definite crystalline compound could be obtained with iron. On the other hand, fused aluminum takes up carbon readily in the formation of the crystalline carbide, Al_4C_3, and the oxides of many other metals furnish similar crystalline compounds when heated in an electric furnace with an excess of carbon. The behavior of these substances with water furnishes the most convenient mode of classification. The carbides of molybdenum, tungsten, titanium, zirconium, the latter having two, and of chromium, also having two, do not decompose water at the ordinary temperature. Of these reacting with water, the carbides of lithian, calcium, strontium and barium furnish a pure acetylene; of aluminum and of beryllium, pure methane; of manganese, a mixture of equal volumes of hydrogen and lethane; while metals of the cerite group give crystalline carbides, all of which react with cold water, forming a complicated gaseous mixture containing hydrogen, acetylene, ethylene and methane. But the most complex reaction is that furnished by uranium carbide with water. In this case, in addition to the gaseous mixture containing methane, ethylene and hydrogen, liquid and solid hydrocarbons are produced in abundance. The carbides of silicon and titanium are extremely hard, the latter even cutting diamond.

TECHNICAL NOTES.

Carbon boride is a new compound of the electric furnace, obtained by H. Moissan, by the heating action of the current in a suitable mixture of boracic acid and carbon. The mode of production is strictly analagous to that of the well-known substance carborundum, or carbon silicide, made by heating in the electric furnace a mixture of silica and carbon.

The new product is reported to possess a degree of hardness superior to that of the diamond, which it readily cuts, and to have the great advantage that it is possible to produce it in pieces of any desired size.

ELECTRIC FURNACE STUDIES.

In the current number of the *Annales de Chimie et de Physique*, M. Moissan continues the account of his researches with the electric furnace. He gives the preparation and properties of titanium, molybdenum, uranium and the borides of iron and of carbon, the preparation of manganese, and an historical account of the researches already made on the crystallized carbides of the alkaline earths. In the latter paper he lays claim to the discovery of crystallized carbide of calcium, while assigning to Mr. Willson the credit of having introduced its manufacture in the United States. With regard to titanium, M.

Moissan has found that with a current of 50 ampères and 50 volts, titanic acid is converted into crystallized oxide of titanium. With 350 ampères and 70 volts, the bronze-yellow nitride, Ti_2N_2, is obtained. When 1,200 ampères and 70 volts are used, the temperature rises above the point of decomposition of this substance, and the carbide TiC is formed, free from nitrogen; and if this is heated with an excess of titanic acid, titanium containing only 2 per cent. of carbon is obtained. These successive actions, says M. Moissan, give a decisive proof of the increase of temperature of the electric arc dependent on an increase of the current, and form the starting point of another long series of experiments. The preparation of the crystallized compound of iron and boron containing over 15 per cent. of boron, and nearly corresponding to the formula FeB, effectually disposes of the assertion of some workers on iron that it is impossible to alloy these two elements.

THE DANUBE SHIP CANAL.

The great engineering work of removing what is known as the "Iron Gates" in the River Danube has been completed, says the *Scientific American*, and on September 27th the new canal was formally thrown open to navigation, with elaborate ceremonies, by Emperor Francis Joseph. His Majesty was accompanied by King Carl, of Roumania, and King Alexander, of Servia. The procession of steamboats which passed through the Iron Gates showed how successfully the work of removing the obstacles to navigation has been accomplished. For forty years the passage of the Iron Gates has been difficult and possible only on an average of 117 out of the 225 days during which navigation is open. The obstruction between Bazias and the Iron Gates has been removed and a canal has been excavated through the Prigada and other reefs of the Iron Gates along the southern or Servian side of the river. The canal through the rocks is about two miles long, 260 feet wide, and 10 feet deep, so that the Danube will now be navigable for the largest river steamers from Vienna to the Black Sea. The whole work cost nearly $10,000,000, and owing to carelessness in blasting operations, some 200 workmen lost their lives. The opening of the Danube to easy navigation will doubtless develop the Danube traffic to a tremendous extent. The formal opening of the canal was the crowning feature of the Hungarian millennium festival.

BOOK NOTICES.

A Text-Book on Shades and Shadows and Perspective. New York: John Wiley & Sons. 1896. By John E. Hill, M.S., M.C.E. 2d edition. 8vo. Pp. 101. 12 plates.

This book is a thoroughly scientific treatment of the subject, and, as the author says, follows descriptive geometry as a logical sequence. For those who believe in and admire the usual collegiate method of training students

in constructive drawing, it is admirable; but to the practical man, who has had a share in doing the world's work, it seems like a waste of the time and energy of the student to make him learn principles, definitions, conventions and an elaborate notation, the application of which he cannot understand until he gets well into the succeeding chapters, and then work out difficult and intricate problems to attain ends which are of no real value. Descriptive geometry is a beautiful science, but it needs revolutionizing on the lines of its useful application to actual work; but so long as all four of the diedral angles are considered and the first angle is made the principal one, when the accepted rule of practice is the third, this is impossible. Planes of projection are imaginary planes, and the practical man would be as apt to draw the shadow of an object on them as to draw the shadow it throws upon space; but when this shadow reaches both the co-ordinate planes and is so delineated, he considers that the height of absurdity is reached.

It is an unfortunate truth, generally recognized, that technical graduates on entering their careers are more poorly equipped in their draughting capabilities than in any other branch of their professions, and this is largely due to their being crammed with an enormous amount of elaborate science, which they only half understand and thoroughly dislike, instead of having their inventive faculties cultivated, and being trained to put their ideas on paper in a clear, detailed, common-sense manner, so as to be easily understood and accurately executed. In the rare cases, where shadows are called for in practice, this book would be useful for reference, but as a part of a technical course it excites profound sympathy for the unfortunate student.

W. H. T.

Alternating Currents and Alternating Current Machinery. Volume II of the Text-Book on Electro-Magnetism and the Construction of Dynamos. By Dugald C. Jackson, C.E., Professor of Electrical Engineering in the University of Wisconsin, and John Price Jackson, M.E., Professor of Electrical Engineering in the Pennsylvania State College. New York: The Macmillan Company. (New York, 66 Fifth Avenue.) 1896. 729 pages, including index. $3.50.

Students of engineering, and of that branch of the profession which has to do with the construction of alternating current machinery, will welcome this addition to the literature on the subject of alternating currents.

The ability to select the general principles from the unimportant and particular matter marks the successful author.

The general plan of the book is to give, first, the underlying principles o electro-magnetism as applying to alternating currents, and then to make the application of these principles to the practical design of machines. The rules and experimental data of good practice have been widely gathered and introduced, yet descriptions of historical and commercial machinery are included only in so far as they stand as types of classes.

Special attention is called to the graphical solution of problems in alternating currents. While mathematics are practically a means to an end, many

persons cannot reason in a purely mathematical way, well enough for the analytical solution. To these the graphical method appeals to the reason through the eye, and to those accustomed to abstract reasoning, the graphical solution will be found to be a material aid.

The book is profusely illustrated with diagramatical drawings. In short, both in the text and in the illustrations, there has been a cutting away of the unnecessary and a boiling down until only the essential remains. In footnotes, the authors refer the reader to articles in current engineering literature for detailed descriptions on special subjects.

The student will find in this work a text-book, and the engineer a book of reference. H. J. L.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, November 18, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, November 18, 1896.

HENRY R. HEYL, Vice-President, in the chair.

Present, 184 members and visitors.

Addition to membership since last report, 1.

Acceptances of election to membership in the Committee on Science and the Arts were presented from Messrs. John Birkinbine, Wm. C. Henderson, Thomas Spencer and Wm. R. Webster.

Mr. Wm. T. Lewis, President of the Horological Society of Philadelphia, read a paper presenting some "Observations on Magnetized Watches." The speaker exhibited, with the aid of the projecting lantern, the results of an experimental study of the subject. (Referred for publication.)

Mr. Louis E. Levy described and illustrated the improvements in glass-gratings for half-tone engravings, devised jointly by himself and Mr. Max Levy. (Referred, for investigation and report, to the Committee on Science and the Arts.)

Prof. Samuel McCutcheon described and exhibited in operation an improved acetylene gas machine, made by the Pennsylvania Acetylene Gas Machine Company.

Mr. Charles F. Chase described and exhibited in operation the Heintz steam-trap. (Referred, for investigation and report, to the Committee on Science and the Arts.)

The Secretary gave some account of the new suspension bridge about to be built over the East River.

Adjourned. WM. H. WAHL, *Secretary.*